ADDIS ABABA SCIENCE & TECHNOLOGY UNIVERSITY

COLLEGE OF ARCHITECTURE and CIVIL ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

The Practice of Application of Delay Analysis Techniques: The case of ERA Federal Road Construction Projects

A Thesis Submitted to Graduate Studies of Addis Ababa Science & Technology University in Partial Fulfilment for the Degree of Master of Science in Civil Engineering, Road and Transport Engineering

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"THE PRACTICE OF APPLICATION OF DELAY ANALYSIS TECHNIQUES: THE CASE OF ERA FEDERAL ROAD CONSTRUCTION PROJECTS"

BY ANTENEH KEBEDE

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"I declare that this research report entitled ***"The Practice of Application of Delay Analysis Techniques: The case of ERA Federal Road Construction Projects"*** is original work of my own, has not been presented for a degree of any other university and that all sources of material used for the thesis have been duly acknowledged."

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DEDICATION

I dedicate this thesis to my dear mother W/ro Muluemebet Zerihun for her decent upbringing, unconditional love, prayers & sacrifices and to my dear father Ato Kebede Gebretsadik leader with stunning qualities.

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ABSTRACT

As in any other construction works, road construction contracts are liable to various kinds of delays with a potential to transform into disputes, this has made it quite essential for contracting parties to identify the delay types & apportion to the responsible party to reach on the right decision on time and/or cost compensation. Over the years various researches has been done to improve the Delay Claim handling procedures, recommendation of standard condition of contracts, improvements on narrative attributes of claims for quantification of the extension of time & cost compensation but only few researches have been done to provide as a guide for handling of delay claims depicting their impact in relation to the work programs, This paper reviews the available industry standard delay analysis techniques, how to appropriately apply them in both retrospective & prospective manner, so harnessing knowledge of the right technique & their proper usage will create a common understanding among the parties involved for a speedy & amicable settlement of Delay Claims.

The data have been collected using questionnaire based on both quantitative & qualitative mixed methods are used to gather the most prevalent delay causing factor & how to appropriately employ the delay analysis technique, the technique to be applied depends on a no of factors mentioned in the research understanding the root causes of delay alerts the claim professional to give more emphasis to that section of operation in order to avoid or mitigate the delay impact.

The data have been analysed using Relative Importance Index, and the degree of agreement among respondents have been confirmed using Kendal Coefficient of Concordance & Spearman Rank Order Correlation in order to ensure the various complementary attributes of the techniques; after computation of the equivalent relative importance index the data is rearranged for factor analysis that have been used to compute which group factors contribute most among the various delay causing factors considered that resulted in Consultant Related, Contractor Related, Equipment Related, Design Related, and External related Factors from highest to lowest factor loading.

The study resulted in improving the programming & record keeping practices of the projects is of paramount importance for the successfully used time impact analysis technique in the Ethiopian Federal Road construction industry with a proactive prevention of the most prevalent delay causing factors that are Shortage of Equipment, Ineffective Planning & Scheduling, and Slow Mobilization of Equipment.

Key Words: Delay, Delay Analysis Techniques, Delay Causing Factor, Programming, Record Keeping, Road, Construction, Ethiopia

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Abbreviations

AACEI	Association for the Advancement of Cost Engineering International
AASTU	Addis Ababa Science & Technology University
BaTCoDA	Building and Transport Construction Design Authority
CPM	Critical Path Method
DA	Delay Analysis
DATs	Delay Analysis Techniques
EC	Excusable Compensable Delay
EN	Excusable Non Compensable Delay
ERA	Ethiopian Roads Authority
ERII	Equivalent Relative Importance Index
FIDIC	Fédération Internationale Des Ingénieurs-Conseils
ICE	International Civil Engineers
IHA	Imperial Highway Authority
ICT	Information Communication Technology
IT	Information Technology
LDs	Liquidated Damages
MOWUD	Ministry of Works & Urban Development
NC	Non Excusable Compensable Delay
NE	Non Excusable
NN	Non Excusable Non Compensable Delay
PDM	Precedence Diagram Method
PMI	Project Management Institute
POW	Program of works
PPA	Public Procurement & Property Administration Agency
RII	Relative Importance Index
RFI	Request for Inspection
ROW	Right of Way
SCL	Society of Construction Law
WBS	Work Breakdown Structure

CHAPTER ONE

INTRODUCTION

1.1 Background

The primary objective during the construction process is to complete the project on time and within budget while meeting established quality standards and other specification (Rasdorf et al., 1992). Unfortunately, delays are becoming an integral part of the construction projects and a basis for most construction claims of road construction projects in Ethiopia.

In construction, delay means a time overrun beyond the contract date or beyond the date the parties agreed upon for delivery of the project (O' Brien et al., 2006).
A 'real' delay may be defined as a period during which a contractor cannot employ his men or machines or staff at their normal intended output, having regard to the nature and amount of work which is available under the agreed program of working or under practicable rearrangement of the program. (Twort et al., 2011)
Delay in general could be defined as "to act slower than desired/planned". (Khaled, 2014)
To the contractor delay means higher indirect costs such as overhead costs, and higher direct costs including material, labor, equipment and escalation costs.
Completion alone does not constitute success for the project owner. For the owner, much of the success of a project depends on many factors, the most important of which is project completion within specified cost and time as delays in completion of facilities often directly equate to financial losses due to lack of revenue from facility operation (Darrell, 1995).

The effects of construction delays are not confined to the construction industry only, but influence the overall economy of a country (Abubeker, 2015).

One of the possible reasons for the delay can be claims management is not normally treated as a management function like estimating, planning, scheduling, and cost control. Most of the time, it is inadequately resourced and performed in an unplanned manner (Vidogah et al., 1997).

The process of preparing Delay Claims starts by identifying the causes and effects of delays/changes. Based on the cause and effect analysis, the responsibilities for delays are determined (Delays are classified) and the entitlements of different parties to time and cost are established. Apportioning project delay among different parties and quantifying damages incurred by each party are then performed (AACEI, 2007).

Collecting documents and analyzing impacts while preparing Delay Claims requires a lot of time & effort. Therefore, it is a costly process. The facts relating to claims must be fully & clearly presented. Schedule variance analysis is a crucial tool to identify, quantify and explain the causes of delays due to each party, therefore it must be accurate, effective & objective (*ibid*).

Consequently, there has been much desire to mitigate or avoid Delay Claim disputes & this has create considerable research interest among Ethiopian researchers & practitioners. Most of the studies undertaken can be classified under four categories as indicated in table 1. The first and the most populated consists of studies aimed at dealing with improving claim handling procedures & alternative dispute resolution methods, and arbitration procedures and their status in the Ethiopian construction industry. The second categories of researches focuses on the planning & programming aspects of the work programs it emphasizes the importance of a well laid construction program is a back bone for a smooth functioning project and backing them with appropriates techniques & ICT paves a proper planning & controlling & taking remedial measures and at the end prevent further delays.

On the third categories consists of those studies at development or refinement of existing delay analysis techniques to address a number of issues that affect whenever a delay situation occurs. The Fourth group has been aimed at identification of delay causing factors & recommendation on improving & remedial measures in resolving the delay situation.

Table 1: Studies conducted for resolving Delay Claims in Ethiopia

Aim of Study/ Problem Addressed	Literature
Claims	
Claims in international Projects in Ethiopia • Investigate causes of claims & propose remedies • Develop a healthy understanding of claims occurrence & formulating A strategy of minimizing risks • Industry lacks qualified engineering professionals with construction Management technique, international contract administration, and claim Handling • Initiate international contract procedure, develop regulated pre-tender document preparation & evaluation measures • Claims related to late handing over of site, RoW problems, design errors, late Submission of drawings, claims related to weather conditions • Industry need to focus on development of adequate project management Skills, establishment of think tank of experts with appropriate negation skills	Girmay(2003)
Review of Arbitration in Ethiopian Construction Industry • Court is not effective in solving construction disputes because of the Technical nature of construction disputes • Acceptance & awareness level of Ethiopian construction parties is Reviewed • There is less awareness & confidence about arbitration • There exists only one local arbitration institute	Daniel(2014)
Studies of the problems of construction conditions of contract • Use of inappropriate & inequitable contract conditions is one of the Problems of the industry for lack of any appropriate development • The objective is to identify drawbacks and short comings of the local Construction industry • Study focuses on provisions related to finance, risk allocation, claim Substantiation & dispute settlement, and practice of contract administration • The finding financial provisions needs improvement • Risk allocation between public employers & domestic contractors' needs to address price escalation and unforeseeable shortage of materials • The claim substantiation & dispute settlement procedure should adopt modern methods & practices • The contract administration practices & attitudes should be improved	Kaseim(2008)

Alternative Dispute Resolution Methods Aberra(2005)

- Non litigation alternatives
- Three known standards conditions of contract(MOWUD,FIDIC,ERA's)
- Dispute/conflict resolution mechanisms preventive, amicable, and judgmental resolution systems
- Consultants do not complete the services in the scope, inadequate quality of design, drawings,specifications,not approve payment on time, and late decision on variations
- Contractors delay on progress & completion of works, do not follow their plans & occurrence of LDs.

Claims in in International Construction Contract Liu(2009)

- Three standard conditions FIDIC, MOWUD,and PPA
- Failure in contract claim management
- Unforeseen circumstances such as variations, adverse climate, and ROW Problem

Claims in Ethiopian Construction Industry Abdissa(2003)

- Standard conditions of contract FIDIC,BaTCoDA,and ICE
- Claims inevitable due to traditional procurement system
- Construction professionals without proper training on construction management
- Main causes improper project management & claim administration
- Claims based on contractual provisions are emphasized

Planning & Programming

Construction Work Programs Dereje(2014)

- Improper work programs root cause for delay
- Most important task identified are define scope of work using WBS, estimate durations, crew size, & historical outputs, defining work calendars, develop activity dependency
- Work program should be updated to recognize delay
- Proper resource utilization is vital to avoid cost overrun
- Major challenges to the preparation of POW, cashflow, delay in site mobilization, climatic conditions, design change, and ROW problem
- Financial resource management & plan cashflow
- Proper planning a head of construction

Work Programming & Implementation Abebe(2014)

- Choice of work programming method
- ROW requirement description
- Design of project logic

- External environmental factors
- Project calendar establishment
- Climatic conditions
- Timely approval of programs by consultant
- Work programs do not assist to track deliverables & milestones
- Improvement on planning & programming is needed

Planning & Scheduling Nejbel(2014)

- Implement principles of constructability
- Rigorous review of the plan, reschedule, and updates

Delay Analysis Techniques

Schedule Delay Identification and Assessment Robel(2015)

- Delay due to site handover & ROW
- Lack of coordination with stakeholders
- External work due to public agencies
- Poor economic conditions
- Delay analysis methodologies(SCL)

Review of Time Extension Delay Analysis Techniques Habtemariam(2016)

- Different stakeholder's involvement makes it differ from other Industry & give rise mostly to unwanted situations like delay or extension of time
- Lack of experience in preparing & evaluating time extension delay analysis in acceptable, procedural, and scientific ways as per the standards stipulated in contract provisions.
- Time at large & no damage for delay provisions are not familiar In Ethiopian construction industry
- There is a need for standard guide manuals how time extension claims to be prepared & settled
- Delay analysis techniques(AACEI)

Delay Causing Factors

Time & Cost Overrun Abubeker(2015)

- Delay to furnish & deliver to site
- Financial problems & improper planning
- Delay in construction
- Inadequate supply of raw materials & equipment

- Design changes
- Incomplete Design

Causes & Impacts of local contractors' time and cost performance Rahel(2016)

- Inadequate planning & scheduling
- Poor project management
- Late possession of site

1.2 Road Construction Development in Ethiopia

There are three perspectives why road construction has been a domain of the state in Ethiopia as cited by Becker/Demissie (2006) in (Momona, 2015). First, from an economic perspective, road infrastructure is a classic example of a public good that is characterized by non-excludability, consequently, the private sector has no interest in providing roads. Hence, road construction has been a domain of the Ethiopian state throughout its history.

Second, from a political perspective, road infrastructure and the accessibility of peripheral rural areas are of crucial importance for the state's "monopoly on the legitimate use of physical force in the territory it is said to control" (Herbst, 2000). From this point of view, it can be argued that the construction of roads has played a significant role in the consolidation of the Ethiopian state since its very beginning (Clapham, 2002).

Third, from a development perspective, road infrastructure constitutes a precondition and decisive factor for development and has therefore to be provided by the state. In fact, road infrastructure in Ethiopia has had a great strategic, political, economic and social significance. The literature and documents on road infrastructure often draw a clear line between different Emperors' and regimes' motivations to construct roads.

During 17th and 18th centuries there were a number of small road trails and foot paths, in addition to the traditional shoulder porterage, animals like mules, donkeys, horses and camels were used as a means of transportation in Ethiopia (Abubeker, 2015).

In the 18th century, especially during the reign of Emperor Tewodros, although the technology was primitive it was believed that planned road construction efforts were made. It is also believed that Emperor Yohannnes IV, who succeeded Tewodros, was engaged in road building. However due to the danger of invasion by Egyptians, Sudanese and Turkish the Emperor was not able to achieve his desires (Organizational back ground of ERA, 2007).

It was prior to the second Italian occupation i.e. between the years 1896 and 1936 that a great success was made in road construction. Emperor Menilik was said to be a successful road builder participating himself in the construction. In 1903 the road from Eritrea to Addis Ababa and the road from Addis Ababa to Addis Alem were built. In addition, it was during this time that the first Asphalt roads appeared in Addis Ababa (*ibid*).

During the Italian occupation roads were built by them and they were established to meet the requirements of the military control rather than to promote the overall development of the country's economy. In addition, the roads lacked most of the modern design and construction features desirable for present day high speed traffic. The roads and trails built and improved during the 5 year Italian occupation were about 6000km. Approximately 2500 km of them were given a single asphalt surface treatment, drainage structures were usually of stone masonry and at least three tunnels were built. However, when Ethiopia regained its independence, the Italians in their fleeing attempt almost undid what they created by blasting bridges and dynamiting roads (*ibid*).
The decade (1941-1951) after the Italian occupation is considered a period of stagnation for the construction and maintenance of the road system. During this post war period, it was felt that a grass root reunification and restructuring program of the already destroyed governmental organizations and systems was required which in turn accelerated considerable stagnation in the whole range of social and economic sectors. Significant magnitude of Italian built road network was deteriorated within a period of 10 years.
In 1951 only 1000 kms of road was traffic worthy of the total stock of about 6000 kms.

In 1951, the Government established a strong and specialized road agency, the Imperial Highway Authority (currently called Ethiopian Roads Authority). The immediate responsibilities entrusted to the newly formed Authority were, first to rehabilitate the already deteriorated road network and second to construct additional road network. From its year of establishment in 1951, the Organization managed to undertake various physical and policy issue assignments.

A program development of road started in 1951 with establishment of IHA. There were six highway programs (ERA, 2009). These were:

a) **First highway program (1951-1957)**: -The program involved a total capital investment of birr 77 million and largely consisted of the reconstruction and maintenance of 1525 km of badly damaged and 2686 km of all-weather roads. The road constructed during this time include: - Addis – Assab (860 km), Addis-Jimma (355 km) and Addis- Nekempt (331 km). Moreover, road maintenance was carried out on Addis-Adigrat, Addis – Blue Nile and Addis-Shashemene trunk roads.
b) **Second Highway Program (1957-1966)**: - The program provided for the continued maintenance and improvement of 4500 km of main highways, for the construction of 800km of new roads and improvement of 1000 km of other existing roads. The amount disbursed in this program is 110 million birr.
c) **Third Highway Program (1966-1968)**: - The program involved a total outlay of Birr 60 million which went into the construction of 700 km of primary and secondary roads, 1000km of feeder roads and 1040 km of asphalt surfacing works.
d) **Fourth Highway Program (1968-1974)**: - During the Fourth Highway Program 820 km of new, primary and secondary roads was constructed. It is during this program that four feasibility studies of future road works and technical assistance and advisory service in the reorganization of the Authority started. The program also included expert assistance in the area of engineering, operation and

maintenance, overseas training with practical orientation for equipment superintendents, foremen and mechanics and others.

Out of the total program of the planned 2246 km roads 1600 km were completed.

e) **Fifth Highway Program (1974-1976)**: - In this program great emphasis was given to the construction of feeder road network to support the agricultural development, strengthening the institutional capability of the Road Agency and providing assistance to the local contracting industry. The program covered the construction of 539 km of feeder road and 322 km of asphalt surfacing projects. It also involved the construction of road maintenance projects worth Birr 14 million and further strengthening of the organization and developing the domestic construction industry.

f) **Sixth Highway Program (1976-1978)**: - During this time the rehabilitation 284 km of primary roads, 280 km of secondary roads, construction of 809 km new gravel feeder road, 657 km of service-to traffic and 1660 km of rural roads were executed.

Beginning 1970, the program of rural road expansion was commenced with major emphasis to improving accessibility and mobility to agricultural potentials.

Since its commencement the Ethiopian Roads Authority has administered the road sector. ERA was established in 1967 by proclamation No 256/67 to provide for the control and regulation of travel and transport on the road. ERA is responsible for the use of all roads within Ethiopia, vehicles using these roads, and to all matters relating to road transport activities of the country. After the downfall of the military government, ERA restructured its obligations with a vision to ensure the provision of a modern, integrated, and safe road transport service to meet the needs of all the communities of a strong and unitary economic and political system in Ethiopia.

When we look at the road network of the country over the past five decades, compared to the year 1951 the total road network has increased with factor seven to reach the level in 2009. In 1951 the total stock of road network was only 6400 km; in 2009 that is 46812 km (ERA, 2009). The rise in the length of road is due to the emphasis given to the sector. In particular, the current government, the Federal Democratic Republic of Ethiopia, has placed increased emphasis on improving the quality and size of the road infrastructure. To address the constraints in the road sector, related to restricted road network coverage and low standards, the Government formulated the road sector development program in 1997. The RSDP has been implemented in five separate phases, as follows:

- RSDP I – Period from July 1997 to June 2002 (5 year plan)
- RSDP II – Period July 2002 to June 2007 (5 year plan)
- RSDP III – Period July 2007 to June 2010 (3 year plan)
- RSDP IV – Period July 2010 to June 2015 (5 year plan)
- RSDP V – Period July 2015 to June 2020 (5 year plan)

1.3 Research Problem

In works contracts of government financed projects, one of the major qualification criteria is performance assessment of contractors on ongoing projects; for the contractors having ongoing projects with ERA, the performance assessment is carried out every month. One of the core performance measurements is the timely completion or progress of projects (i.e. whether the actual accomplishment is equal to or greater than the planned projected accomplishment)

Based on Ethiopian Roads Authority Summary of local contractors' performance evaluation at the end of September 2016 reporting period, 12 ongoing projects out of 40 current projects undertaken by local contractors have undergone a delay of 32 to 735 days that is 1.6% to 40% delayed more than their original contract time. (ERA, 2016; Appendix B)

In the lights of these problems this research therefore tries to assess the practice of delay analysis techniques & the related delay causing factors in ERA's Federal Roads Construction Projects.

1.4 Research Questions & Objectives

In relation to the above highlighted focus area, the study addresses the following research questions:

- What are the most prevalent delay causing factors in practice, to what extent they transform in to disputes & get resolved during the course of the project?
- What type of delay analysis techniques are commonly practiced in the construction sector and to what extent the industry is aware, use, and the success rate of the techniques for resolving Delay Claims?
- What are the factors considered in selecting the appropriate delay analysis technique & the obstacles to the use of these techniques, and how could the delay analysis be improved?

In pursuit of addressing the above questions, the study has been embarked with the following specific objectives:

- To identify the most prevalent delay causing factor in road projects administered under Ethiopian Roads Authority.
- To investigate into the planning & programming issues associated with Delay Claims resolution.

- To assess the practice of delay analysis technique in the Ethiopian Road Construction Industry.

1.5 Significance of The Study

Reviewing the existing techniques in use as reported in the literature provides up-to-date information on the subject matter to researchers & practitioners.

The current status of DAT usage amongst Ethiopian construction organizations has been established based on questionnaire survey areas addressed includes level of awareness, use, success & evaluation of factors influencing the selection of DAT; the findings of this investigation can be used to create common understanding between stakeholders in enhancing speedy & amicable settlement.

Generally, this research will particularly assist clients, consultants and contractors in identifying potential delay causing factors before it happens & the handling techniques once it happened.

1.6 Brief Research Methodology

The first part of the research method involves establishing the basis for the research such as identifying the problem followed by a through literature review, in order to study the current practice in analyzing delays. A systematic analysis will then be performed utilizing a test case network, to assess the current available delay analysis techniques, outlining their advantages and deficiencies, succeeded by a data collection of the existing techniques in the Ethiopian Road Construction Projects and suggest improvements to the current practice: -

- Conduct a comprehensive literature review of delay analysis techniques & delay causing factors.

- Collect data using questionnaire survey on the existing delay analysis techniques and delay causing factors in Ethiopian Road Construction Industry and
- Identify the limitations of the delay analysis techniques and propose improvements.

In reviewing the delay analysis techniques primavera project planner(P6) has been used, for analyzing and ensuring the reliability of the research instruments Descriptive Statistic, Relative Importance Index Analysis, Kendall Coefficient of Concordance & Chi-Square tests, Spearman Rank Order Correlation Test, Factor analysis, and Reliability Analysis (Using Cronbach's Alpha) has been done using SPSS & Excel. A more detailed research methodology is provided under chapter 3.

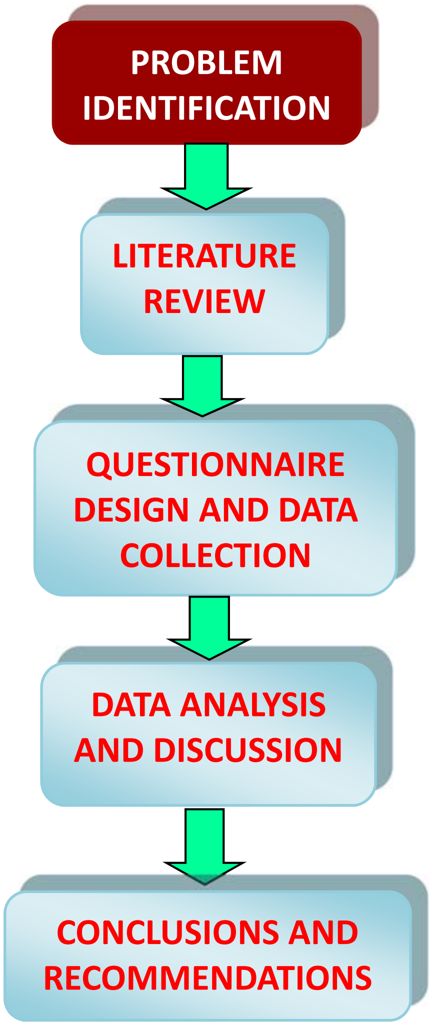

Figure 1: Research Strategy

1.7 Scope and Limitation

This study focuses on local contractors & consultants who have got a substantial work contract with Ethiopian Roads Authority and their head office located in Addis Ababa, whereas the Ethiopian government is undertaking project through the different road authorities such as Addis Ababa City Road Authority & Regional Rural Road Authorities including foreign contractors and consultants.

This research is limited to the time delay analysis of claims without including the financial implication & disruption claims or loss of labour productivity analysis.

1.8 Structure of the Thesis

***Chapter One* - Introduction: -** This presents a general overview of the thesis comprising of the research background, the research problem, the research objectives and questions, the significance of the study, brief research methodology, the scope & limitations of the research. It also gives a general guide to the contents of the thesis.

Chapter Two - **Literature Review:** - This chapter reviews literature on Delay Claims as a basis for identifying the most prevalent delay causing factors, it also reviews issues of planning and programming that affects delay analysis. Deficiencies in existing practice as reported in the literature and their possible causes will be identified, and finally this chapter identifies and evaluates the various delay analysis techniques mentioned in the literature using a test case together with factors affecting their use are identified and reviewed critically as well.

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Chapter Three –**Research Methodology:** - This chapter explains the methodology adopted in carrying out the research, the reasons for adopting it and how it facilitated the achievement of the research objectives, it also sets out the survey procedure used in analysing data collected and its justification.

***Chapter Four* – Results & Discussions: -** This chapter reports on the findings of the questionnaire survey undertaken to establish the current state delay analysis practice in Ethiopia. This provided basis for the identification of associated major problems and the development of an appropriate improvement.

Chapter Five - **Conclusions and Recommendations:** - The conclusions derived from the research and recommendations for promoting good practice are presented in this chapter. Suggested recommendations for further research are provided as well.

CHAPTER TWO

LITREATURE REVIEW

2.1 Introduction

The ever present goals of meeting the triple constraints scope, time and cost are the major considerations throughout project's life cycle (Abebe, 2003); planners focus on specific methods to meet project's scope goals. This preoccupation for improving scope delays the schedule and pushes up the costs.

In addition to time, cost and specification there is a fourth dimension to be considered; this fourth dimension is the expectation of the client which at many instances increases as the project progresses; however, it seems that expectation of the client is not an additional target but inherent part of the project specification. To consider the client's desires as different from the project specification is to court conflict between client and project team. (Darnel, 1997).

Scope takes precedence at the beginning, cost during high activity and schedule during the final stages, research found out scope & schedule are more important than cost during all stages. (*ibid*).

Wubishet (2004) suggests the application of time performance evaluation as critically important criteria in bidding process in Ethiopia construction industry because the Government of Ethiopia waived the use of completion time and allowed low evaluated cost award system for tender evaluation in 1993. Accordingly, the consultant shall estimate a reasonable time for the completion and announce the same on invitation to bid and the estimated time for completion should satisfy the interest and schedule of the client.

On the other hand, however, many contractors tend to give as low a price as possible so that the highest financial weights in the selection process may be obtained. The reason for this is that the contractor will be in a better position to win the contract and if selected, he may make up the difference in the money needed to make a good profit through claims. It seems therefore that the selection of contractors through a lowest bid tends to tempt contractors to claim later on. (Girmay, 2003)

For handling Delay Claims there are two schools of thought as a result of two guidelines society of construction law(SCL) delay and disruption protocol (2002 & 2017) the AACEI (Association for the Advancement of Cost Engineering) Recommended Practice (2007 & 2011).

The Ethiopian Roads Authority when established as Imperial Highway Authority(IHA) in 1951 it was founded with technical assistance from the USA(Neil,2016) and from this historical point of view the researcher adopted the techniques from AACEI but the SCL protocol was also used for its well versed recommendations such as resolving concurrent delays, so both have been utilized for this research.

There are quite few researches done on delay analysis techniques in contrast to researches on delay causing factors, planning & programing issues or claims in general in Ethiopia. As per one of the important selection factors/criteria (which is adopted from AACEI) section 4.7.5 skills of the analyst (with RII 99) shows its prominence as confirmed in this research, the analyst can choose any technique from any of the guide lines which he is familiar with and he thinks appropriate for the claim analysis.

SCL is based on English common law & while AACEI is set up by the American Association of Cost Engineers and reflecting the American view of delay analysis and extensions of time.

The aims of the two guidelines are similar but with slightly different emphases. AACEI has a stated aim of providing a "unifying reference of basic technical principles and guidelines for the application of critical path method (CPM) scheduling in forensic schedule analysis" whereas the SCL provides "useful guidance where one party wishes to recover an extension of time and/or compensation for the additional time spent and the resources used to complete the project.*"* Neither guideline seeks to overturn explicit contract provisions for dealing with Delay Claims. (Sean,2017)

"The AACEI guideline can be seen as related to the technical aspects of quantification, a planners' guide for instance, whereas the SCL is focused more on matters of administration and entitlement. Arguably this should make the guidelines complementary. In other words, work out the delays in accordance with an AACEI recognized methodology, assign liabilities and then justify entitlement by reference to SCL"(*ibid*).

The review covered a wide range of issues including: (i) the major delay causing factors; (ii) planning and programming issues affecting time overrun; and (iii) existing delay analysis techniques & their application using a test case network. The findings of the literature review formed the basis of the subsequent questionnaire design and data collection.

2.2 Researchers' Major Delay Causing Factors

Many studies have been conducted in different countries to identify the factors affecting delay in construction projects. Mahamid (2011) indicated that the most severe factors affecting time delay in road construction projects in the West Bank in Palestine from the owner perspective are: poor communication between construction parties, poor resource management, delay in commencement, insufficient inspectors, and rework.
Odeh and Battaineh (2002) found that contractors and consultants agreed that owner interference, inadequate contractor experience, financing and payments, labor productivity, slow decision making, improper planning, and subcontractors are among the top ten most important factors of construction delay in Jordan.
Assaf and Al-Hejji (2006) discussed the delay in large construction project in Saudi Arabia. Seventy-three factors affecting time overrun were identified during the research. They

concluded that the most common factor of delay identified by contractors, consultants and owners is ‘‘change order’’.

Koushki et al. (2005) conducted a study in Kuwait to study the causes of time and cost overrun in construction projects. They concluded that the main causes of delays are change orders, financial constraints, and lack of experience by owners. They stated the following recommendation to the owners in order to minimize time delays:

1) Project owners should require the availability of adequate funds,
2) Allocation of sufficient time and money at the design phase
3) Selection of a competent consultant and reliable contractor to carry out the work.

Asnaashari et al. (2009) presented the result of an investigation into the main factors which cause construction delay in Iran. The results reveal that most of construction projects in Iran are subject to delay. Cash constraints, shortage of resources, high inflation rate, delay in payments, and disputes in the supply chain are the top causes of delay in the Iranian construction industry.

Faridi and El-Sayegh (2006) studied the delay in construction projects in UAE and concluded that 50% of the construction projects encounter delays and are not completed on time. The top significant causes of construction delays are approval of drawings, inadequate early planning and slowness of the owners’ decision-making process.

Mezher and Tawil (1998) conducted a survey of the factors affecting time overruns in the construction industry in Lebanon. It was found that owners had more concerns with regard to financial issues; contractors regarded contractual relationships the most important, while consultants considered project management issues to be the most important factors affecting time overruns.

Kaliba et al. (2009) concluded from their study that the major causes of delay in road construction projects in Zambia were delayed payments, financial deficiencies on the part of the client or contractor, contract modification, economic problems, material procurement, changes in design drawings, staffing problems, equipment unavailability, poor supervision, construction mistakes, poor coordination on site, changes in specifications, labour disputes, and strikes. It can therefore be concluded that the most important factors vary from one region to another.

Table 2: Summary of Previous Studies on Delay Causing Factors in Construction Projects World Wide

Researher (Year)	Country of Origin	Major Causes of Time Overrun
Kikwasi G.J(2012)	Tanzania	- Design Changes - Delays in payment to contractors - Information Delays - Funding Problems - Poor project management
Girmay(2003)	Ethiopia	-Exchange of information b/n government agencies -Right of way/Site handing over problem - Significant design change
Baldwin et al. (1971)	United States	- Inclement weather - Shortages of labour supply - Subcontracting system
Murali et al.(2006)	Malaysia	- Contractor's improper planning - Contractor's poor site management - Inadequate contractor experience - Inadequate client's finance for completed works. - Problems with subcontractors
Arditi et al. (1985)	Turkey	- Shortages of resources - Financial difficulties faced by public agencies and contractors - Organizational deficiencies - Delays in design work - Frequent changes in orders/design - Considerable additional work

Researher (Year)	Country of Origin	Major Causes of Time Overrun
Rafiq et al.(2012)	Pakistan	- Delay in progress payment - Extreme weather - Contractor's incapability - Land Acquisition & Resettlement - Ineffective planning & scheduling - Scope changes & additional work
Robel(2015)	Ethiopia	- Delay in delivering material onsite - Poor site management - Incomplete documents - Delayed Site handover
Dlakwa and Culpin (1990)	Nigeria	- Delays in payment by agencies to contractors - Fluctuations in materials, labour and plant costs
Chan and Kumaraswamy (1996)	Hong Kong	- Unforeseen ground conditions - Poor site management and supervision - Slow decision making by project teams - Client-initiated variations
Semple et al. (1994)	Canada	- Increases in the scope of the work - Inclement weather - Restricted access
Kumar et al.(2006)	India	-Commitment of project participants - Owner's competence - Project manager's ignorance & lack of knowledge - Hostile socio economic environment
Assaf and Al-Hejji (2006)	Saudi Arabia	- Change order by the owner during construction - Delay in progress payment - Ineffective planning and scheduling - Shortage of labour - Difficulties in financing on the part of the contractor

Researher (Year)	Country of Origin	Major Causes of Time Overrun
Faridi and El-Sayegh (2006)	UAE	- Slow preparation and approval of drawings - Inadequate early planning of the project - Slowness of owner's decision making - Shortage of manpower - Poor site management and supervision - Low productivity of manpower

Assessing the actual causes of delay, the extent to which delay may occur and the impacts of delay can provide insights for early planning to control projects delay and improve project performance (Adiam, 2016).

2.3 Float Versus Critical

Float time is a valuable concept in scheduling, since it indicates those paths of activities where some flexibility is allowed in the scheduling of work (Hendrickson et al., 1989). Moreover, noncritical activities may become critical when float time is used up by the delay. The problem arises when the float is consumed by delays, and the party that owns the float applies the first come first served basis (Ockman, 1988). Several opinions on the use of floats have been suggested in the literature (Householder et al., 1990). Be it owner or contractor, the float belongs to the project, and when exclusive use of the float used by one party is determined at the undue expense of the other, adjustment is required. Since the float could impact the whole project duration, the exclusive use of the float by one party should not be at the expense of the other (Hohns, 1979). Rather than introducing adversary relationship on projects, it is good to recognize that float exists for the benefit of all participants (Ritcher et al., 1982). There are a number of contracts that do not clearly state which party will receive the benefit of float time.

2.4 Schedule Variance Analysis

The objective of the analysis is to measure the magnitude of the time impact due to the responsible party and determine the corresponding damages. Several scheduling documents are utilized in analyzing the time impact on the project completion date. Scheduling techniques critical path method or bar charts are normally used to evaluate delays resulting from a specific impact.

2.4.1 As-Planned(Baseline) Schedule

At the start of each project or after the receipt of letter of acceptance, an original work schedule is prepared by the contractor according to the contract documents, which is the as-planned schedule. This schedule reflects the contractor's planned approach to pursue the work, and illustrates only the planned activities, their duration, their relationships, the critical path, and the project start & finish dates. Inorder for this schedule to be accepted in delay analysis, it must show that the relationship between activities are reasonably valid, the durations realistic, the productivity rate based on common standard performance, the planned resource allocation feasible, and the schedule has allowed for foreseen conditions such as weather conditions, work restrictions, constraints, and time for inspection and approvals (Reams, 1990).

Once established and approved, the baseline is set in stone, and become the *schedule of record* (Frank et al., 2007).

2.4.2 As-Built Schedule

As the job progresses, new conditions appear and the schedule is updated in order to calculate the new project duration if it had been impacted. Thus at the end of the construction project, a new schedule is established which is the as-built schedule (Alkass et al., 1996). This schedule could be prepared from project records.

The as-built schedule reflects the actual succession of events that took place during the execution of the project, while the facts are taken from project progress reports, RFI etc.

2.4.3 The Adjusted As-Planned Schedule

To reflect the sequence of events which transform the as-planned schedule in to the as-built schedule, a series of adjusted schedules are prepared thus explaining the major schedule variances which occurred during the course of the project (Arditi et al., 1989). The adjusted schedule reflects how the as-planned schedule has been affected by delays, accelerations, or other changes, when they are incorporated in the schedule.

2.4.4 The As-Projected Schedule (Adjusted As-Built)

During the updating process, if the project is not yet complete an as-projected schedule is performed which will show the expected project completion date. This schedule includes the as-built data for the completed part of the project and the proposed changes in the remaining changes (Arditi et al., 1989)

2.4.5 The Entitlement Schedule

Entitlement schedules are also used in order to determine the impact on the project completion date, due to excusable delays (Reams, 1990). They also depict the difference between the adjusted and the projected completion dates. Care has to be taken in this procedures, since the critical path analysis is a dynamic phenomenon, and might reflect a theoretical path different from the real one, when only some impacts are incorporated in the as-planned schedule.

2.5 Types of Schedule Impacts

2.5.1 Delay

A delay is an event that prevents the contractor from completing the work within the contractually specified performance period (Wickwire et al., 2003), a slowing down of the work without stopping it entirely, triggered by something other than a formal directive from the owner to stop work (Bartholomew, 2002). Simply put, a delay is a loss of time. Any party involved in the project can cause delays, however most claims involve alleged delays caused by the owner.

Damages from pure delays are those resulting from an extended performance period, including increased overhead and job site costs, equipment standby costs, wage escalation, and financing costs (Wickwire et al., 2003).

2.5.2 Disruption

A disruption can be defined as an impact that alters the contractor's planned work sequence or flow of work expected at the time of bidding, which results in increased difficulty, cost, and/or time. When this occurs, the contractor cannot perform work in the manner anticipated during bid preparation, thus resulting in a schedule impact. As opposed to delays, damages associated with disruption are likely to be increased labor costs due to inefficiency, the activation/deactivation of increased manpower, and additional equipment costs (*ibid*)

2.5.3 Change

Another major type of potential schedule impact involves changes. When a contractor takes on any type of work that deviates from the original contract, or from the scope of work or plan of action reasonably anticipated under the contract, that results in an increase in performance time, the contractor may seek an adjustment (Bramble et al., 1990). Before determining the impact of the change on the schedule, the change must be identified as truly being a change from the original contract or merely a situation that should have been anticipated by the terms of the original agreement (*ibid*). Changes can be broken down into three categories:

Directed Changes: A classic directed change order involving a directed written modification to the contract (1) directs the contractor to make specific changes to the work required by the project plans and specifications, (2) acknowledges that a change has been made, and (3) invokes the directed contract change order provisions. The directed change to the contract should state the increase, or decrease in the case of a deletion, in total time for contract performance (Bramble et al., 1990).

Constructive Changes: An informal or constructive change lacks the formality of a directive authorizing a change in the work; "a change that is not acknowledged by the owner as such when it occurs, but which nonetheless is a change" (Bartholomew, 2002). The owner's action or inaction has an impact on the contractor, taking the position that whatever the contractor is directed to do or is prevented from doing is not a change, but rather is required or prohibited by the original contract, as the case may be.
The contractor then proceeds with the owner's request for the constructive change, but then they must give prompt written notice of the constructive change to the owner (Bramble et al., 1990).

Cardinal Changes: A cardinal change is a change (either directed or constructive) that is clearly beyond the general scope of the contract, so extensive as to change the entire character of the work required under the contract (Bartholomew, 2002).

2.5.4 Suspensions

A suspension of work is a written directive by the owner to stop all work on the project, either because the contractor has failed to perform in accordance with contract documents, or at the owner's convenience (Wickwire et al., 2003). Work will not continue until the owner has raised the suspension of work. A cost and time adjustment shall be made for any suspension of work ordered by the owner, as long as the contractor was not responsible for the suspension of work. As opposed to a pure delay, when an owner issues a suspension of work, the contractor is also entitled to equitable adjustment for profit (*ibid*).

2.5.5 Termination

Termination is a permanent stoppage of work of all or a portion of the contract, and the contract is terminated. For a party to possess the right for termination, a termination clause must be specifically included in the contract. Most contracts allow the owner the right to terminate the contract, while some contracts grant the contractor this right.

There are two categories of termination, the first type being default termination, which gives the owner the right to terminate the contract when the contractor's performance is either:

1. Far behind a reasonable time schedule or
2. Results in work that fails to meet contract quality requirements or
3. When the contractor becomes financially insolvent. (Bartholomew, 2002)

The second type of termination, convenience termination, allows the owner to terminate the contract for its convenience, based on specific needs of the owner. For example, if the owner is unable to fund the remainder of the project and there is a termination for convenience clause in the contract, the owner is allowed to terminate the contract.

2.6 Causes of Delay

2.6.1 Owner/Consultant

Owner initiated changes to the original contract can be: -

- Additional Quantity of work
- Design change
- Faulty Design
- Failure to compensate or relocate settlements in the right of way
- Differing site condition arise from contract misrepresentations
- Suspension of work

- Change orders
- Improper project feasibility study
- Delay in progress payments
- Lack of experience of consultant in construction projects
- Delay in approving major changes in the scope of work
- Delay in performing inspection and testing by consultant
- Late in reviewing and approving design documents
- Complexity of project design
- Insufficient data collection and survey before design
- Lack of experience of design team in construction projects

2.6.2 Contractor

Delay analysis encompasses finding the impact of any event that may influence project completion. This includes actions on behalf of the contractor for which they are held accountable. The following is a list of possible events that cause contractors delays:

- Poor workmanship that causes rework
- Failure to supply the Four M's: Money, Materials, Machinery, Manpower
- Failure to coordinate subcontractors and lower-tier subcontractors
- Failure to perform job site investigate (pre-bid visits and geotechnical investigation)
- Incompetent project team
- Failure to follow contractual obligations
- Ineffective project planning and scheduling
- Obsolete technology
- Slow mobilization of equipment
- Poor site management and supervision
- Frequent equipment breakdown
- Improper equipment

- Poor Environment, Safety & Health Administration
- Frequent Accidents during construction due to negligence

2.6.3 Third Party / Force Majeure

Force Majeure impacts are commonly known as unforeseen events, causes beyond the contractor's control, and events without fault or negligence. Common examples of delays that are beyond the control and without the fault of the contractor include but are not limited to:

- Acts of God or of the public enemy
- Acts of the Government in either its sovereign or contractual capacity
- Fires
- Epidemics
- Quarantine restrictions
- Global financial crisis
- Strikes
- Freight embargoes
- Unusually severe weather. (Wickwire et al., 2003)

Under such provisions, the contractor is entitled to an extension of time to complete work if the delay is deemed excusable. An Act of God typically refers to a natural occurrence caused directly and exclusively by natural forces without any human intervention, which could not have been reasonably foreseen or prevented by the contractor or any other party to the contract. This category includes earthquakes, landslides, tornadoes, hurricanes, lightning, and floods.

Liquidated damages are not to be assessed during this extended performance period, provided the delay is not directly or indirectly the fault of the contractor. Abnormal weather conditions can greatly influence the execution of activities, in turn affecting completion of the project on time.

Most contract documents state that the only weather that should impact the completion of the project within schedule is “unusually severe” weather conditions. Weather can have both a direct and indirect impact on construction. For example, if unusually severe rainfall amounts stop all earthwork activities, there is a direct effect and stoppage of work. In addition to the days that the rain has taken place, the indirect effect of the rain is that the earthwork activity cannot be started until the soil has dropped to a workable moisture content.

In dispute resolution, courts evaluate weather delays on a case-by-case basis, considering such factors as the job site’s geographic location, the nature of the work performed, the contractor’s previous experience in the area, and the contractor’s reasonable anticipation of weather conditions (Wickwire et al., 2003). Anticipating weather can be done by looking at historical data for typical “rain days” in the same geographic location, accounting not only for the time of year, but also for that specific location. Weather impacts are not strictly limited to rain and the rainy season; also included but not limited to are abnormal humidity, frozen earth, extreme heat, severe weather outbreaks, and wind (Bramble et al., 1987).

2.7 Classifying Delays

Once recognized that an event has occurred in the as-built completion of a project that differs from the established schedule of record, which potentially has an impact on the schedule and is attributable to a party, the next step is to classify the delay, so that a delay anlysis technique can be applied. Delays are classified into one of the following five categories (Trauner et al., 2009):

1. Critical, Non Critical
2. Excusable, Non-Compensable Delays
3. Excusable, Compensable Delays
4. Non-Excusable, Non-Compensable Delays
5. Non-Excusable, Compensable Delays

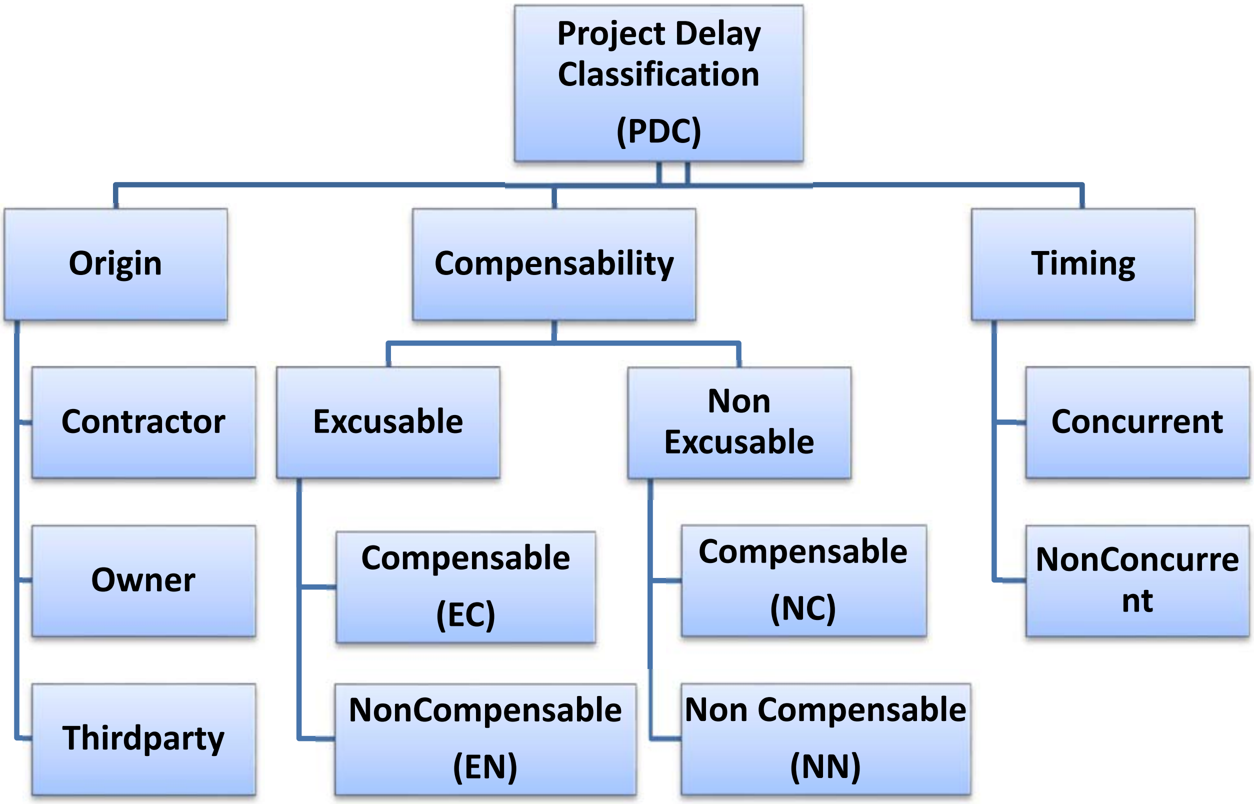

Figure 2: Types of Delays (Source: Kartam, 1999)

2.7.1 Critical, Non-Critical

According to Trauner et al. (2009), the primary focus in any study of delays in a project is to see if the delay affects the progress of the entire project or the project completion date. The authors further state that delays which result in extended project completion are considered critical delays, and delays that do not affect the project completion date are known as noncritical delays. Trauner et al. (2009) further claim that the issue of critical delays emerges from the CPM scheduling. All projects have a critical path and if these critical activities on the path are delayed than the completion date of the project will be extended. The criteria determining the project completion date are as follows (Trauner et al., 2009):

- The project itself
- The contractors plan and schedule (particularly the critical path)

- The requirements of the contract for sequence and phasing
- The physical constraints of the project - how to build the job from a practical perspective.

2.7.2 Excusable, Non-Compensable Delays (EN)

An excusable, non-compensable delay (EN) is a delay that will serve to justify an extension of the contract performance time, a cause of delay that is not attributable to either the contractor or owner. This includes all third party / force majeure causes of delay. A contract may include risk-allocation provisions that define those types of project delays that are not attributable to either party, excusing them from meeting a contractual deadline. Prior agreements about whether certain delays are the risk of the owner or the contractor will, to a large extent, determine whether a delay in performance of work is excusable or non-excusable.

2.7.3 Excusable, Compensable Delays (EC)

Excusable, compensable delays are classified as “Owner Responsible Delays,” or an “EC”. An EC, in addition to granting time extension, warrant monetary compensation to the contractor for extra costs incurred – commonly referred to as delay damages. Generally, compensable delays constitute a delaying event that is within the control of, is the fault of, or is due to the negligence of the owner. A compensable delay occurs when

(1) The delay is caused by the owner or someone within the owner’s control,
(2) The delays result in actual monetary damages to the contractor, and
(3) The contractor has not assumed risk to delay through a “No Damages for Delay” clause (Wickwire et al., 2003). If such a clause should exist in a contract, the contractor is entitled to seek time extension for owner-caused delays, but not compensation.

On projects with contracts that do not contain a "No Damages for Delay" clause, the following is a list of possible compensable delays:

- Owner's failure to furnish the site to the contractor by an agreed date
- Faulty design
- Incomplete drawings and specifications
- Changes in scope
- Suspension of work
- Differing site conditions
- Late delivery of owner-supplied materials

When drafting the contract, the contractor may wish to include a clause specifically related to compensable delays (also referred to as owner-caused delays), which reinforce the contractor's right to recover damages under and express warranty. However, not doing so will not prevent the contractor from making future delay damages claims for compensable delays (Frank et al., 2007).

2.7.4 Non-Excusable, Non-Compensable Delays (NN)

Delays caused by the contractor's actions and/or inactions are considered nonexcusable, non-compensable delays – also referred to as a "Contractor Responsible", or "NN." Non-excusable delays can be the fault of the contractor, his subcontractors, or suppliers. When such a delay occurs, the contractor is entitled to neither time extensions nor compensation. In fact, in addition to possible extra costs incurred by the delay of work, the contractor may be held liable for liquidated damages a predetermined monetary amount that must be paid by the contractor to the owner for days in which the contractor delayed project completion. Liquidated damages are not meant to be a penalty, but a realistic estimate of additional costs to the owner caused by the contractor's delay.

It is often difficult for owners to ascertain non-excusable delays by the contractor because owners not always maintain construction schedules or records sufficiently detailed to identify either the contractor's delay or why it occurred. This downfall can be solved by keeping a detailed, updated construction schedule that establishes the start and finish dates for particular activities and field records that identify why a delay occurred.

2.7.5 Non-Excusable, Compensable Delays (NC)

The fifth classification of delay, non-excusable, compensable delay, is a peculiar situation in which an owner and contractor are concurrently delaying the project, and compensation for the owner's delay can be properly apportioned. While monetary compensation may be awarded, no time extension is granted for the period. The owner delay is shown on the schedule; however, it is important to note in this situation that no time extension will be granted for the owner's delaying event, this can be the case of owner's initiated acceleration measures.

2.8 Concurrency

2.8.1 Concurrent Delays

Not all delays occur independently of each other, often taking place during the same time and/or on separate parallel paths of the CPM network.
When more than one type of delay happens at the same time and both, either together or independently, impact the project's critical path, a concurrent delay occurs (Arditi and Robinson, 1995). Concurrent delays add more complexity to the delay analysis. Mohan and Al-Gahtani (2006) indicated that the three major difficulties in calculating concurrent delay are as follows:

1. It is difficult to agree on the concurrency period of two or more delay events. The concurrent delay events may occur with respect to two or more concurrent activities which have different start and finish dates; thus only portions of these activities are concurrent.

2. New critical paths could be formed because of consuming the total floats for noncritical activities.
3. If the concurrent delays are on critical paths, and if the owner delays the critical path, the contractor can decelerate his work on the parallel critical paths in order to be critical.

Rubin et al.(1983) suggested the following guide line for calculating concurrent delays:

- If Excusable & Nonexcusable Delays happen concurrently, only a time extension is granted for the contractor.
- If Excusable Compensable & Excusable Noncompensable delay occur concurrently, the contractor is entitled to time extension, but not to damages.
- If two excusable compensable delays occur concurrently, the contractor is entitled to both extension of time & damages.

This adjustment is valid if the concurrent delays happen on a critical path (Kraiem et al., 1987). Although such guidelines are useful for delay analysis, it is in the best interest of all parties involved in a construction project to agree at the start, about the definition of such delays and to accommodate them in to the contract.

2.9 Existing Delay Analysis Techniques

The critical path method is necessary to help evaluate the cumulative effect of time overrun on the project duration. The CPM is superior and used more often than the bar chart method in claims situation (Hohns, 1979). If a CPM as-planned schedule doesn't exist, a claim analyst must prepare one from the contractor's bar chart (Reams, 1990). In the past claims were based on "Barnyard door" (McCullough, 1989). This was a narrative approach of the delays with an attached bar chart, comparing the as-planned to the as-built schedules, without cause-effect link analysis. All data & reports presented in hope of getting some compensation. Neither party knew exactly what delays were justified. So claims were escalated, and settlements were low and unfair.

Several techniques and procedures for analyzing delays have been currently recognized by legal authorities to determine the effect of delaying events up on the total project duration. An event may delay an activity, but not the entire project. Those delays are to be analyzed according to the right of using the float. Not all the available delay analysis techniques are appropriate to analyze a delay in a given situation.

Determining the delay analysis technique depends upon a variety of factors including the value of the dispute, the time available, the records available, the funds and effort allocated to the analysis, and the analyst's judgement & expertise (Leary et al., 1988).

The most common techniques currently available to be used in the construction industry include (Leary et al., 1988):

1. Global Impact,
2. Net Impact,
3. But for(Collapse),
4. Adjusted As-Built CPM
5. Snapshot (Window Analysis)
6. Time Impact
7. Isolated Delay Type

Table 3: Delay Analysis Techniques Comparison (Frank et al., 2007)

	BASED ON:	
	AS-PLANNED SCHEDULE	**AS-BUILT SCHEDULE**
Retrospective Techniques	**Net Impact** *After the fact, inserting delays into the as-planned to quantify global impact.*	**Adjusted As-Built CPM** *After the fact, insert delays into asbuilt to show "critical path" and quantify global impact.*
	Isolated Delay Type *After the fact, inserting delays into an updated as-planned to quantify impact.*	**Collapsed As-Built (But-for)** *After the fact, delays are subtracted from as-built to quantify global impact.*
Contemporaneous Techniques	**Isolated Delay Type** *At the time of delay, inserting delays into an updated as-planned to quantify impact.*	**Snapshot/Window Analysis** *At time of modification, schedule is updated and delay inserted to quantify singular impact.*
		Time Impact Analysis *Recreate time of modification. Using updated schedule, insert delay and quantify singular impact.*

The first four retrospective techniques look back on project delays once the project is complete, and then apportion responsibility, while the last three techniques analyze the effects of delay in a contemporaneous manner and they are prospective techniques.

2.9.1 Global Impact Technique

The global impact technique is a simplistic approach to depict the effect of delay causing events. It is often used by claimants in their initial requests for time extension, usually during the construction phase. In this method, all delays and similar occurrences are simply plotted on summary bar charts. The delay start & finish dates are determined for each event, and the duration of each delaying event is computed. The total extension of time of the project is calculated to be the sum total of the durations of all delaying events (Leary et al., 1988).

2.9.2 Net Impact Technique

This method depicts only the net effect of all claimed delays on a bar chart. In implementing this technique, all delays, disruptions, and suspensions, even change orders are plotted on as-built schedule. The main argument focuses on the combined overwhelming effect of all delays on the completion date of the project. Thus only the net effect of delays is calculated and the requested time extension is then the difference between the as-planned and the as-built completion date. The net impact technique unlike the global impact attempts to deal with the issue of concurrent delays (Leary et al., 1988).

2.9.3 The Adjusted As-Built CPM Technique

This technique utilizes the CPM format to develop an as-built schedule for the entire project. Delaying events are depicted as distinct activities and linked to the specific work activity in the network by restraints. The adjusted as-built completion date and the as-planned completion date is the amount of time the claimant would ask for compensation. The as-built CPM method may weed out minor delays that would not affect critical activities. This technique is similar to the net impact technique in that both techniques only show the net effect of all claimed delays on the project completion date (*ibid*).

2.9.4 But for(Collapse) Technique

The basic concept of the But For technique is that the opposite party can be shown to be liable through a CPM analysis, that deals with the two parties' impacts separately. Delaying events for which the claimant is willing to accept responsibility is incorporated in to the as-planned CPM schedule, and the recalculation of the project completion date is performed. The as-built schedule is compared to the adjusted schedule(Calculated), and the conclusion drawn is that the difference between the as-built and the revised completion dates is the time effect of delays which were beyond the claimant's control. The duration of the claimed delays will be subtracted out from the total variance, leaving the balance to the other party (Leary et al., 1988). But for the other party's delays, the project would have been completed in a timely manner.

If the contractor is using this method the analysis would include only nonexcusable (Contractor's fault) delays in to the as-planned schedule. The result of the adjusted schedule would generate a revised completion date, which is due to contractor's delays. The difference between the as-built and the revised completion date is due to the owner. The logic is that despite all of the contractor's delays the project is still impacted which is the responsible of the owner, and the rest of the total delays is due to the contractor. Conversely, the owner can use the same technique, but would include in to the as-planned schedule, only excusable delays for which the owner accepts responsibility.

2.9.5 Snapshot Technique

The snapshot technique is used to determine the amount of delay that has occurred on a project, the time when the delay occurred, and what was the cause of the delay (Tardif, 1988). The snapshot technique utilizes the as-planned, the as-built and any revised schedule that have been implemented during the execution of the project. The total project duration is divided into a number of time periods, or snapshots. These snapshots dates are usually selected to coincide with major project milestones, significant changes in planning or when major delays or group of delays are known to have occurred. For the first snapshot the analysis starts by inserting the delaying events into the as-planned schedule, and a new schedule duration is generated. In the next snapshot the durations and the relationships of the activities are taken from the as-built schedule, for the snapshot period, and are incorporated into the schedule generated from the previous snapshot, thus an extended duration schedule is established. The new completion date is compared to that of the project prior to performing the snapshot under consideration. The difference between the two completion dates is the amount of delay that affected the project as a result of the delaying events which have occurred during the snapshot period. Once the time impact has been determined, the causes of delays are assessed.

Before starting the next snapshot analysis, the schedule has to be revised, if necessary, to reflect the planning of the project at that point in time under consideration. When the revisions are done, the difference in the project completion date of the extended duration and the revised extended duration schedules is an indication of acceleration (or relaxation) achieved through change in planning. The revised extended duration schedule now becomes the baseline schedule for the next snapshot analysis.

The snapshot technique starts with the as-planned schedule and the delay analysis is progressively performed for each determined snapshot period. The total delay is calculated by summing up all the delays associated with each time period, disregarding any time period gained through acceleration. The measurement of the time impact is inclusive of both direct and indirect consequences of a delay-causing event. The extended time is then analyzed for apportionment of responsibility between the owner and the contractor (Tardif, 1988).

2.9.6 Time Impact Technique

The time impact technique, is similar to the snapshot technique in examining the effects of delays at different times in the project. But the difference is that the time impact technique focuses on specific delay not at a time period containing delays. The idea is to obtain a “stop action” picture of the project before and/or after encountering a major impact on the schedule (Leary et al., 1988). The as-planned is first verified to reflect the contractor’s actual plan, and second, it must be updated at certain critical periods in the construction process, thereafter the actual duration of the project is established. The delay is inserted into the schedule, the project duration is recalculated, and a new project completion date is determined. The difference between the two completion dates is the effect that the delay had on the project at the time it was inserted into the schedule.

This Technique is progressively applied for each delay or delaying event which is to be analyzed. In order to obtain an accurate impact upon the overall project completion date, the schedule should be updated with actual dates and durations prior to incorporating the analyzed delay. This ensures that critical paths are accurate at the time of the delay is being analyzed. By adding all the individual time impact analyses, a total impact of delays on the project completion date is determined. This amount of total delays is then analyzed for apportionment between the owner and the contractor (Leary et al., 1988).

2.9.7 Isolated Delay Type Technique

In performing the isolated delay type technique, which applies only the relevant portion of the delays in the time period, with in an as-planned schedule. Comparing the project's completion date before and after inserting the delaying events may generate a change in the project's completion date. The discrepancy is attributed to the delay that was incorporated into the schedule. When applying this technique from the contractor's point of view, excusable compensable and excusable non compensable delays are incorporated in the schedule in order to calculate an adjusted schedule. This schedule is compared to against the previous one and the variance is the amount of time the contractor was justifiably delayed (Mazerolle et al., 1993).

However, to find the amount of time the contractor can seek compensation, only excusable compensable delays are incorporated in the schedule and the difference between the two completion dates is calculated. Conversely, the owner can use this technique to measure the amount of time that he is entitled to liquidated damages from the contractor. The nonexcusable delays would be incorporated to determine a new adjusted schedule, thus the discrepancy between the two schedules would be the amount of time to quantify the liquidated damages. (*ibid*).

2.10 Choosing The Right Methodology

As a general rule, there are 11 different items that should be considered in choosing the right delay methodology, as published by AACEI, remain in place (AACEI, 2007).

They are:

1. Contractual Requirements
2. Purpose of Analysis
3. Source Data Availability and Reliability
4. Size of the Dispute
5. Complexity of the Dispute
6. Budget for Forensic Schedule Analysis
7. Time Allowed for Forensic Schedule Analysis
8. Expertise of the Forensic Schedule Analyst and Resources Available
9. Forum for Resolution and Audience
10. Legal or Procedural Requirements
11. Custom and Usage of Methods on the Project or the Case

2.11 Planning and Programming issues

2.11.1 Project Planning and Control

Project planning has been also defined as "the process of selecting one method and order of work to be used on a project from among all the various methods and sequences in which it could be done" (Callahan *et al.,* 1992).

According to Arıkan and Dikmen (2004) the main purpose of planning is to provide the primary duties of the manager, namely direction and control. The second objective of planning is to organize all the relationships and information systems among the many parties involved in the construction project. The third function of planning as enabling project control and forecasting.

The contractor wants to complete the project as quickly as is economical because every day spent on site costs money. Furthermore, cash flow is the lifeblood of the contractor; without it he will not survive. Achieving the scheduled monthly progress helps the contractor to meet his cash flow requirements. While employers and contractors have similar goals, they have differing needs and expectations from the schedule (Dereje, 2014).

Once a project has begun, the schedule becomes essential to the successful coordination of day-to-day activities and acts as a baseline for measuring progress. When accurate site events are recorded and entered into the schedule, CPM analysis can help project managers anticipate problems that may occur in the future (Gould, 2005).

Using the difference between actual and planned progress, management can initiate appropriate corrective actions, such as replanning, rescheduling, or increasing the level of resources. This dynamic cycle of reviewing the current status and forecasting future requirements is one of the primary purposes of project control (Ahuja et al., 2004).

Contractors Need Planning & Scheduling in order to accomplish the following: -

- Finish the project on time.
- Continuous (uninterrupted) flow of work (no delays).
- Reduced amount of rework (least amount of changes).
- Minimize confusion and misunderstandings.
- Increased knowledge of status of project by everyone.
- Meaningful and timely reports to management.
- Knowledge of scheduled times of key parts of the project.
- Knowledge of distribution of costs of the project.
- Accountability of people, defined responsibility/ authority.
- Clear understanding of who does what, when, and how much.
- Integration of all work to ensure a quality project for the owner. (Mubarak 2005)

2.11.2 Relevant Issues Not Addressed by Existing delay identification techniques

In addition to the different results that existing delay analysis techniques produce when applied to the same set of Delay Claims data, there are other relevant issues that have the potential of affecting the results but are often not taken into consideration in the techniques applications. These issues include: resource loading and levelling requirements, resolving concurrent delays, and delay pacing strategies.

2.11.2.1. Resource Loading and Levelling Requirements

The basic assumption underpinning traditional CPM program that resources are unlimited does not hold in reality as resources tend to be limited in most practical situations (Nuhu, 2013). It is thus quite important for baseline programs to be resource-loaded so as to ensure both reliable task duration and network logic, especially when many tasks require the same resources at the same time. Without such loading, the program to be used for delay analysis would not show realistic float values in its non-critical activities, and would thus affect the outcome of the analysis; especially for cases involving time extensions claims resolutions. Therefore, a resource loading or levelling consideration in delay analyses is quite crucial for ensuring accurate and trustworthy results, except for the but for(collapse) as-built technique as it does not rely on baseline programs.

It is noteworthy that the need for analysts to take resource allocations into account in their delay analyses is becoming an increasingly vital requirement. (Wickwire, 2002) reviewed legal decisions in the US and noted that "in any analysis of project delays, the contractor is required to take into account realistic resource levelling". Although the incorporation of resource loading effects in the analysis represents a more accurate and rigorous assessment of Delay Claims, there is very little research on how this consideration can be incorporated in the existing techniques.

2.11.2.2 Resolving Concurrent Delays

The identification and apportionment of concurrent delays remains a contentious technical subject. More debilitating is the fact that there is no uniformly accepted definition among practitioners as to what it concurrent delay itself means. A reliable approach for analysing concurrent delays would involve using dynamic multiple time periods or windows, as this is capable of tracing changes in the critical path (SCL, 2017).

However, in such mode of analysis, identifying the concurrency and the type of concurrent delays within a given period will be dependent on the length of time chosen for the analysis period. Therefore, analysts using different time intervals are bound to interpret a given concurrent delay situation differently. To enhance amicable settlement of claims, analysts would have to agree on the analysis time interval to be used, which can either be based on dates at which program updating occurred or the occurrence of key project events such as project milestone or major changes in the program. The legal aspects of concurrent delays concerning the kind of remedies to be offered to parties have also continued to remain a highly contentious issue. (Frank et al., 2007), for example, it was found that UK practitioners hold dissenting views to the SCL's recommended remedies (SCL, 2017), which stipulate that, for employer and contractor delays occurring concurrently, the parties should share the responsibility between them and extension of time without costs also awarded. In addition, existing case laws that could offer some guidance on the remedies do not speak in harmony (Frank et al., 2007).

This lack of consensus or clearly defined rules/methods for dealing with remedies of concurrent delay types poses great difficultly to practitioners in Delay Claims resolution. There is therefore the need for research into the underlying principles that governs the legal resolution of concurrent delays to establish clear guidelines for dealing with all possible concurrency situations.

Employers may subsequently incorporate these in their contracts for it to guide claim parties during Delay Claims resolutions.

2.11.2.3 Pacing Delays

Zack (2000) defined this as "deceleration of the project work, by one of the parties to the contract, due to a delay to the end date of the project caused by the other party, so as to maintain steady progress with the revised overall project schedule". The thinking behind pacing delay is that it is sensible for a party to slow down the working pace if a delay by other party makes it unnecessary for hard or fast working, as often memorably argued, "Why hurry up and wait". It enables the contractor or the employer to mitigate or avoid cost that otherwise would have been incurred had the work been done faster. However, there are difficulties in exercising the right to pace delays, which can affect the delay analysis process. For instance, float ownership, will determine whether a particular

contractor-caused delay could be a potential employer's defence of concurrent delay or otherwise. Furthermore, as argued by (Zack, 2000), pacing delays tends to minimize compensable delay and this makes it imperative to consider its effect in delay analysis process to ensure fairness in the apportionment of delay responsibility.
Further studies are thus needed to offer assistance on how to resolve these issues.

2.11.3 Deficiencies in Contractors' Programmes

Most construction contracts require the contractor to provide a programme at the start of the works to show the sequence and timing of the construction activities. Not only do programmes serve as tools for managing projects, they are also valuable sources of information for identifying and modelling delays and their effect on progress. For the programme to be appropriate for this function, it has to be free of any form of deficiencies (Reams, 1990).

However, a number of researchers have observed that most contractors' programmes have deficiencies thereby making the resolution of time overruns disputes more difficult.
In addition, contractors are reluctant to provide details of envisaged resources in their programmes thus making it difficult to assess the impact of delays on usage of resources and their productivities in the event of delays (Yogeswaran et al., 1998).

There are obvious benefits to proper programming, it is surprising that many contractors do not provide employers with a proper programme and then manage it appropriately. Hence most constructors' programmes are likely to suffer from a number of deficiencies. Typical of the deficiencies that will impair their utilisation for delay analysis include: poor baseline programmes, failure to update programmes, and inadequately updated programmes. These deficiencies can lead to difficulties and disputes in resolving claims.

2.11.3.1 Poor baseline programmes

The baseline programme submitted by the contractor is the initial as-planned programme that reflects the intended plan for executing the project. Its importance in delay analysis lies in its ability to demonstrate the period of time within which the contractor would have completed the project absent any delays. Shortcomings in baseline programmes that often make them invalid or unreliable tools for this purpose include the following.

i. Programmes prepared in a format other than CPM: Except in simple Delay Claims, CPM format is the highly recognised tool for proving delay because it allows the determination of the critical path and shows the interrelationships among multiple causes of delay (Kallo, 1996b).
ii. Incomplete programmes: That is failing to include all the work that must be undertaken. This makes it difficult to evaluate how all activities and their delays interact to affect project completion (Bramble and Callahan, 2000).
iii. Insufficient details provided for the programme activities: improper schedule density that is not stable throughout the WBS, hence this makes it difficult to measure progress and the effect of delays adequately.
iv. Unreasonable logic or relationships between activities: Such relationships do not accurately represent the contractor's intended sequence of work (Reams, 1990), and thus would result in erroneous delay analysis results.
v. Unrealistic planned resource allocations. This results in incorrect duration and cost allocation of activities making the baseline programme unreliable (Kartam, 1999).

2.11.3.2 Failure to update program

Programme updating is reviewing periodically the plan and progress of work. This is necessitated by the fact that the uncertain conditions in which construction projects operate inevitably cause plans and estimates to change (Laufer et al., 1994).

As a result of the inevitable changes in construction projects, failure to update the programme would result in lack of important information such as:

- Changes in critical path;
- Actual start and finish dates and percent complete for each activity;
- Milestone status and potential problem areas;
- Logic changes from previous updates

2.11.3.3 Inadequately updated program

An updated programme that does not adequately reflect the contractor's as-built progress as the project unfolds would not be able to accurately predict project delays and their impacts. Thus, to maintain the updated programme as a realistic tool for assessing delays, it has to be a competent one. There are different approaches to updating which can affect the adequacy of updated programmes (Nuhu, 2013).
One approach is updating the programme as and when the scheduler deems it necessary. For instance, updating the programme when the project falls behind schedule or when unexpected changes in the programme occur as required by some contract documents. Other factors affecting the adequacy of updated programmes are the degree of detail of the updating. As a minimum in each updating process, the following have to be identified: actual start dates, actual finish dates, percent complete and remaining durations per schedule activity (Kursave, 2003). The accuracy and timing of these data are also very important in the production of proper updated programmes.

2.12 Application of Existing Delay Analysis Techniques

2.12.1 Introduction

Delays are the most common and costly problem encountered in construction projects. In a construction project where time truly equals money, the management of time is critical (Duran, 2006), thus predicting the likelihood of schedule delay may play a key role towards project success (Luu et al., 2009). Contractors continue to absorb costs that would have been compensable if properly identified, documented and claimed. Several delay analysis techniques are currently utilized by practitioners, and they range from simple dates comparison to tedious and time consuming detailed analysis, any of which can yield a wide variety of results. Since the ultimate goal in preparing a delay analysis is to present accurate and credible results as supportive documents in a claim, which is the major step towards proving the effects of delays, it is necessary to ensure that the technique applied is persuasive.

The objective of this chapter is to discuss effective delay analysis technique currently available in the industry, by applying each technique to a common test case, analysing the results, and highlighting their shortcomings and advantages.

2.12.2 Test Case

After each delay has been isolated from other delays and assigned to one of the categories, the next step is to identify when the delays occurred and their effect on project completion.

To better assess the existing delay analysis techniques, a test case has been adopted from literature, (Kraiem et al., 1987). The test case is suitable for the analysis since it is simple, while consisting of ten activities and two critical paths, it comprises all the diverse types of delays which are well laid out. The scheduling software used in the process is primavera P6.

Fig. 3 Shows the as-planned CPM schedule of the test case, which consists of ten activities split into three paths. For the assessment of the delay analysis techniques, the PDM format was used for its simplicity in being handled by the scheduling software.

The PDM schedule, representing the CPM schedule, is broken down into the following activities:

- Activities 1,3,6 and 9; Critical Path
- Activities 2, 5, 8 and 10; Critical path
- Activities 2, 4 and 7; Non-Critical path.

The project's as-planned duration is 23 days from the start of the completion (Fig. 3) The as-built schedule (Fig. 4) maintains the same activities and relationships but includes many delays throughout the schedule, extending the total project duration by 18 days to become 41 days. Fig. 5 shows the comparison between the as-built and as-planned bar charts.

The delays identified in this test case are categorized into three types; excusable noncompensable(EN), excusable compensable(EC), and nonexcusable(NE).

The following is a breakdown of the delays according to their type and duration in days, within each activity:

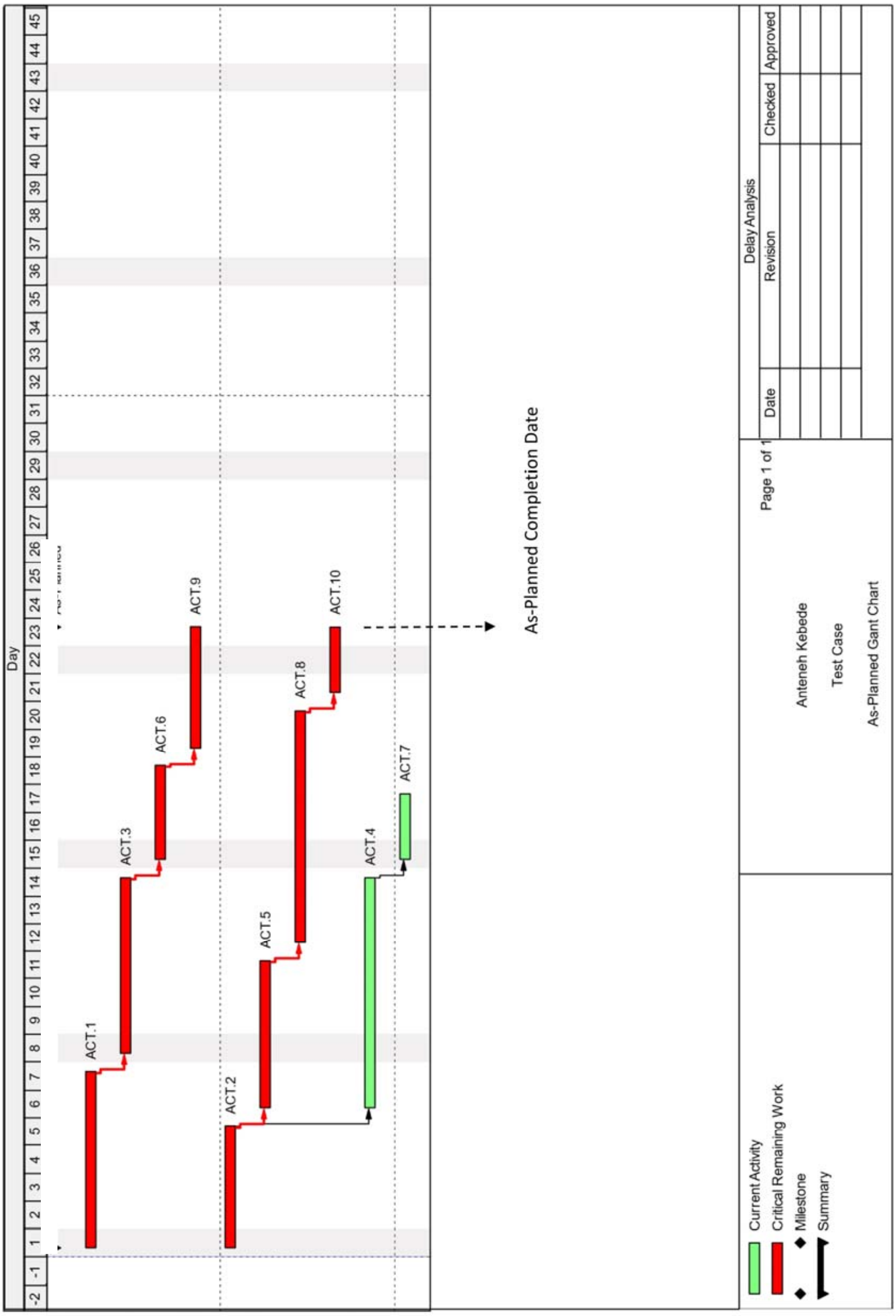

Fig. 3: As-Planned CPM Schedule; Test Case

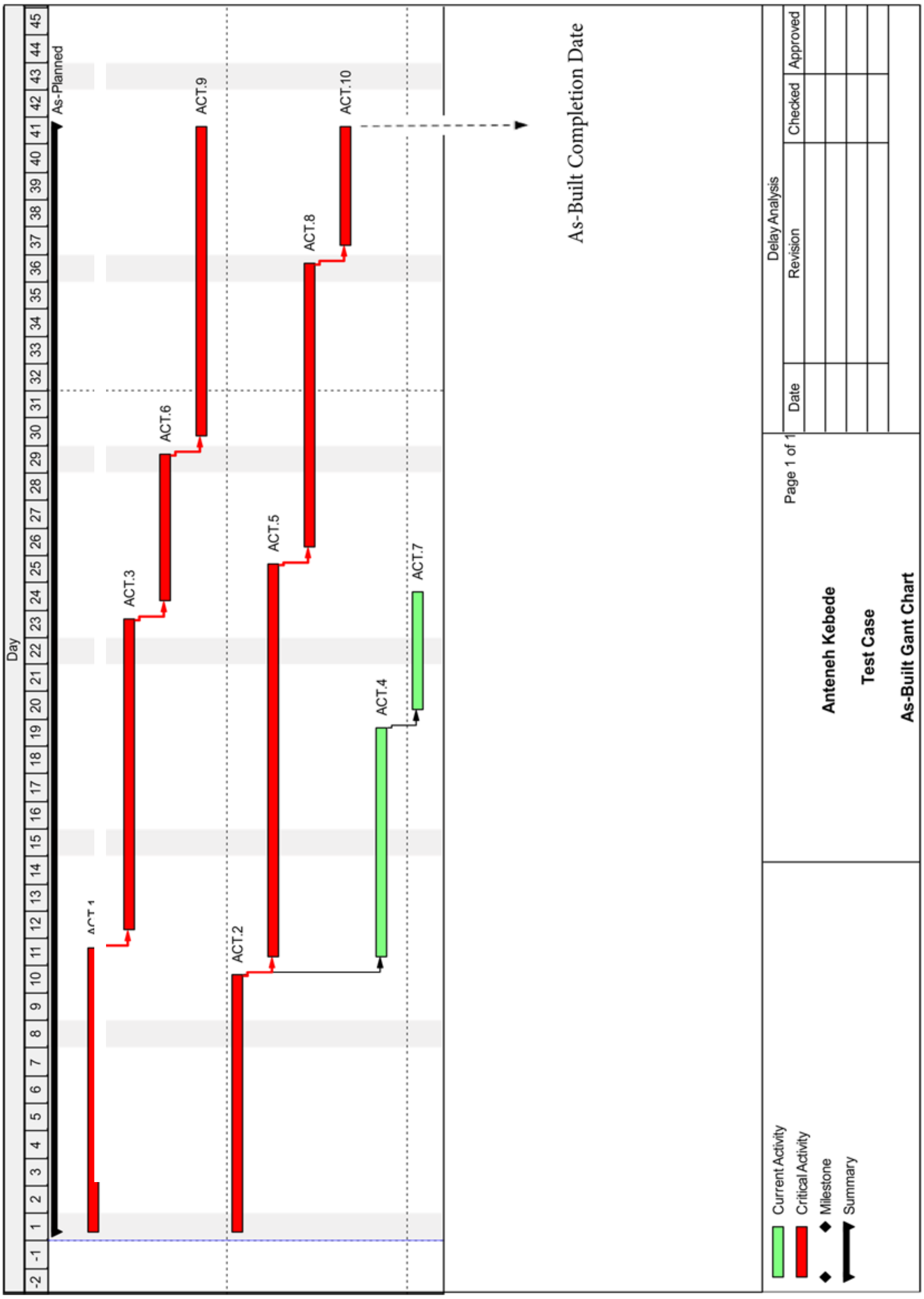

Fig. 4: As-Built CPM Schedule; Test Case

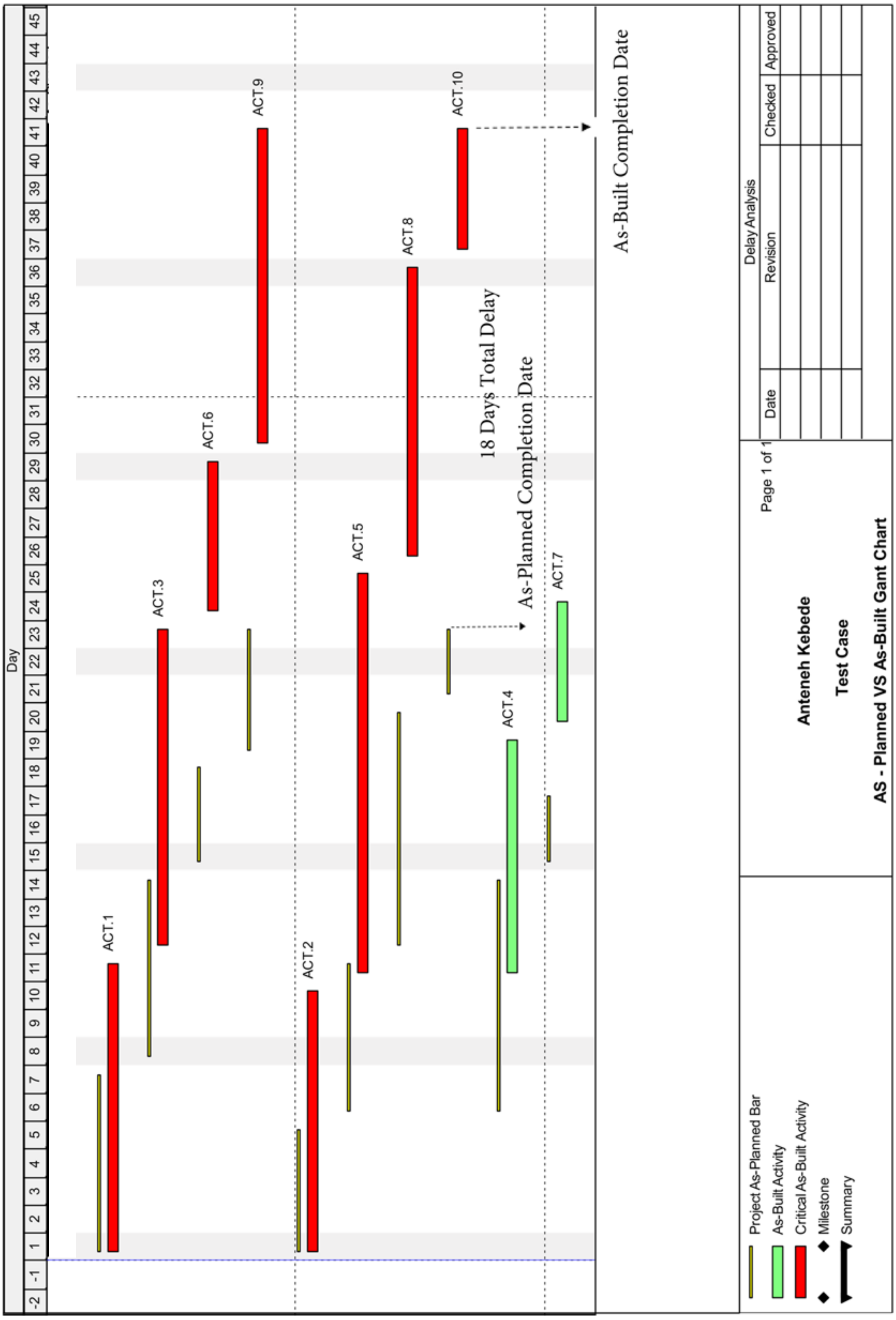

Fig. 5: As-Planned Vs As-Built; Bar Chart

Activity 1: EN – 1(occurred on Day 1), NE – 3(occurred on 2,3 & 7 days);
Activity 2: EN – 3(occurred on 5,6 & 7 days), NE – 1(occurred on day 3),
EC – 1(occurred on day4);
Activity 3: NE – 3(occurred on 12,13 & 14 days), EC – 2(occurred on 15 & 16 days);
Activity 4: -
Activity 5: EN – 5(occurred on 19,20,21,22 & 23 days), NE – 1(occurred on day 16),
EC – 3(occurred on 13,14 & 15 days);
Activity 6: EC – 2(occurred on 24 & 25 days);
Activity 7: NE – 1(occurred on day 23), EC – 1(occurred on day 22);
Activity 8: EN – 1(occurred on day 30), EC – 1(occurred on day 33);
Activity 9: EN – 2(occurred on 33 & 34 days), NE – 3(occurred on 35,36 & 39 days)
EC – 2(occurred on 32&40 days);
Activity 10: EN – 2(occurred on 37 & 38 days)

2.12.3 Assessment of Existing Delay Analysis Techniques

The following delay analysis techniques were assessed using the test case

Global Impact

Net Impact

Adjusted As-Built CPM

But for contractor's delays; owner's point of view

But for owner's delays; contractor's point of view

Snapshot

Time Impact

Isolated delay type; contractor's delays

Isolated delay type; owner's delays

Starting with the same as-planned schedule, as-built schedule, and using the appropriate delays, each technique was applied to the same test case. The following sections contain descriptions of the delay analysis.

2.12.3.1 Global Impact Analysis

To perform the global impact technique, the duration of the delaying events identified in the test case were summed to determine the total delay to the project. Using a bar chart representing the as-planned and as-built schedules as summary bars, as illustrated in Fig. 6 an additional summary bar showing the total delay in addition to the as-planned duration was simply included on the bar chart, to indicate the duration to which the contractor is entitled to accomplish the project. The total amount of compensable delays is 38 days which is the summation of all delays that occurred on the project, while the project completion date overrun was 18 days.

There are many problems with the global impact technique. The main issues that the global disregards, are: the effect of concurrent delays, and the classification of delay types thus assuming that all delays have an impact on the project. Moreover, even without concurrency the global impact assumes that any delay would have impacted the overall project completion date thus considering all activities to be critical. This frequently results in a contractor's claim for time extensions which extend well beyond the actual project completion date; the rationale is that the difference between the entitlement completion date and the as built completion date is the amount of time saved by acceleration (Leary et al., 1988). While this technique is simplistic, it is inaccurate in depicting the impact of delays. However, it is often used by claimants during the initial requests for time extensions.

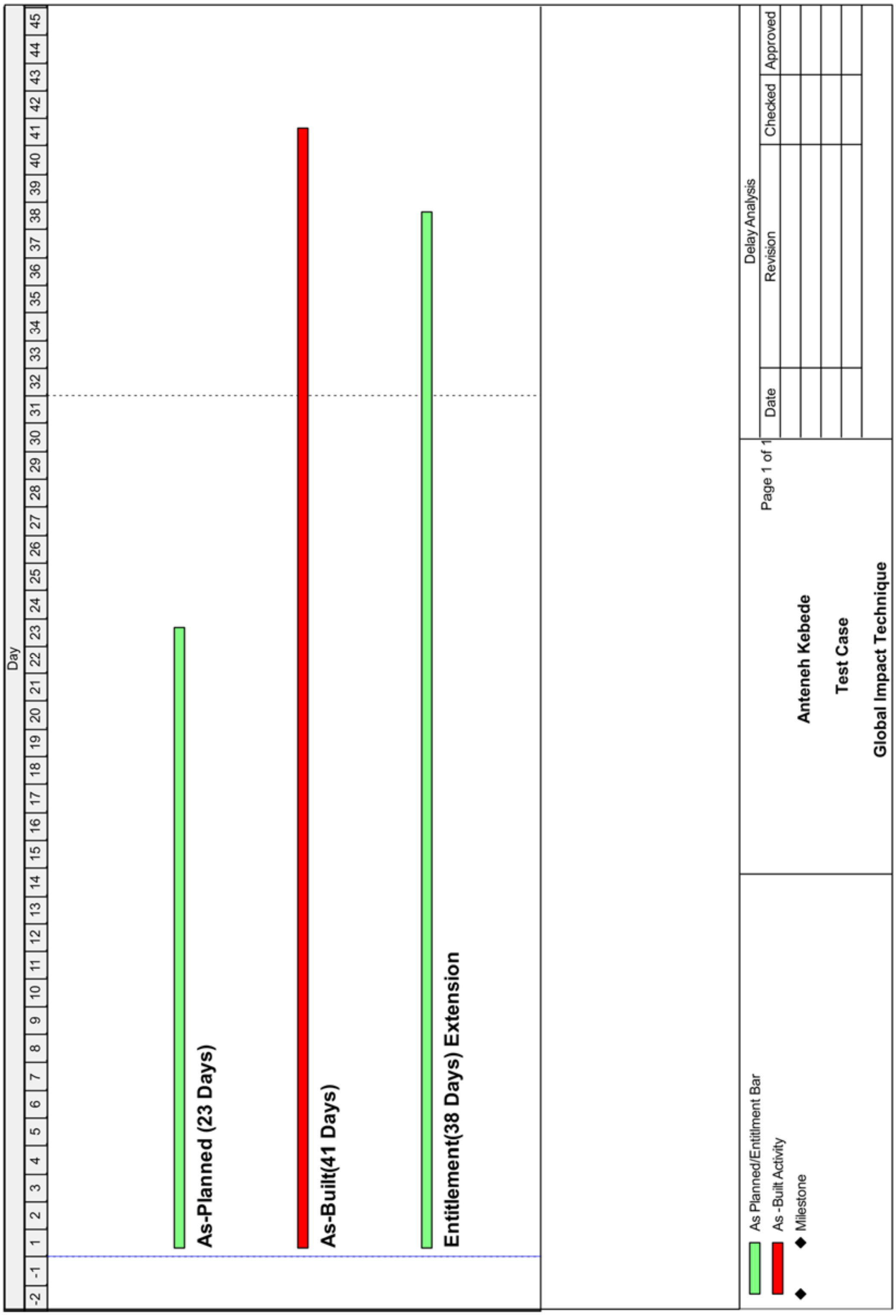

Fig. 6: Global Impact Technique

2.12.3.2 Net Impact Analysis

Inorder to avoid the problem of concurrency faced with in the global technique, claimants use another technique, called net impact technique. It depicts only the net effect of all delays on a bar chart. The time extension claimed for, is the period from the as-planned completion date to the actual completion date of the project.

In implementing the net impact technique, all delaying events in the test case were plotted on an as-built schedule, as shown in Fig. 7 the net impact in this case is 18 days which is the difference between as-built and as-planned completion date. It is argued that the combined overwhelming effect of delays impacted the project, rather than the duration of each individual delay.

Although the net impact technique avoids the problem of concurrency, it does not scrutinize the types of delays. this results in an overstated amount of time requested for the claiming party. Further, without the use of network analysis scheduling techniques, it would become inaccurate to calculate the impact on the overall project due to any delay (Leary et al., 1988)

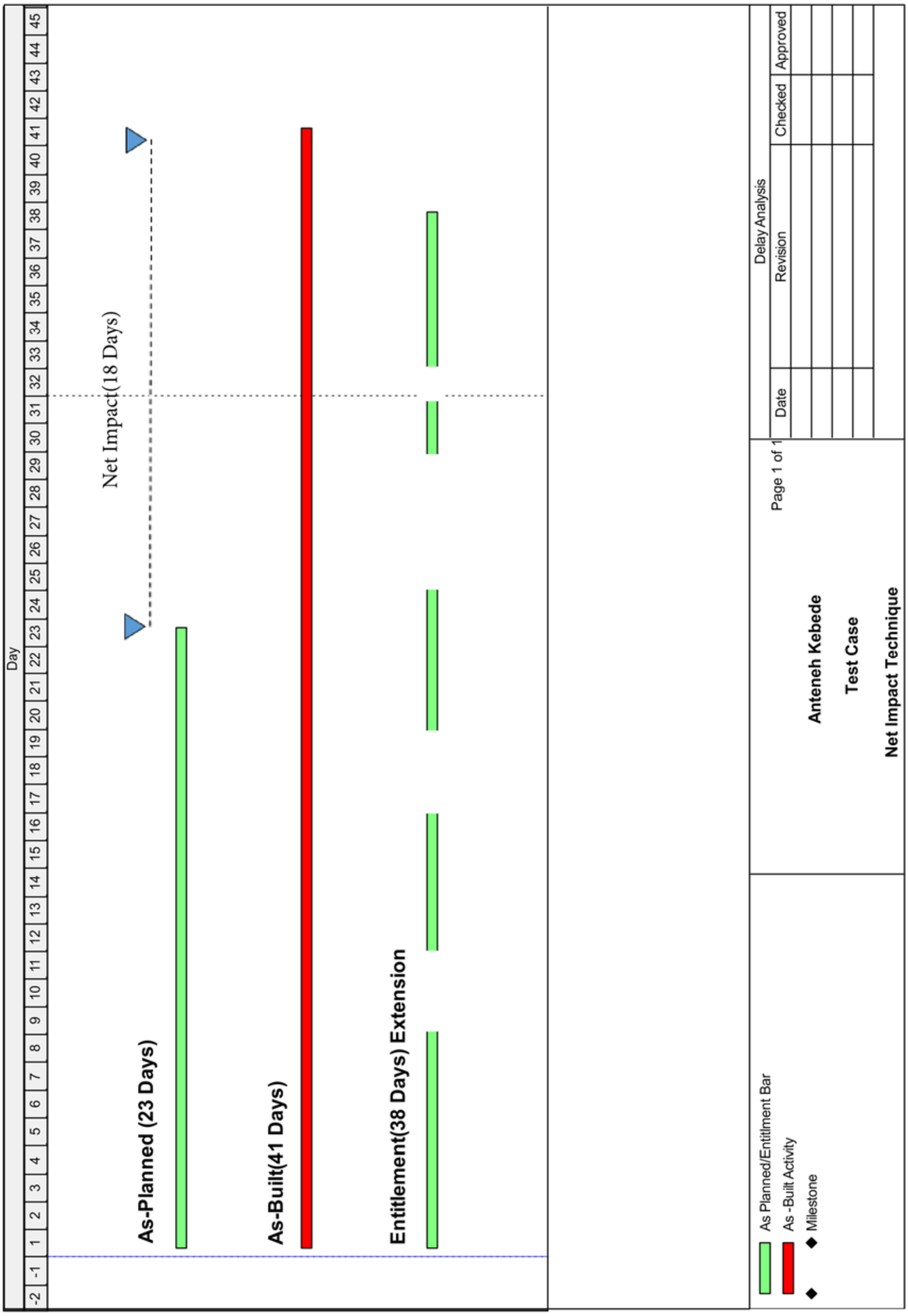

Fig. 7: Net Impact Technique

2.12.3.3 Adjusted As-Built CPM Analysis

In applying this technique to the test case an adjusted as-built schedule for the entire project was developed, using the CPM format. All the delaying events were incorporated in the as planned schedule, as independent activities which were tied to the original activities by restraints. Fig. 8 illustrates the CPM schedule generated from the application of the adjusted as-built CPM technique. A new critical path was established to the project. Similar to the net impact this technique accounts for the net effects of delays, which is the difference between 41 days adjusted completion and the 23 days of the as-planned completion duration resulting in 18 days for time extension.

Although the adjusted as-built CPM technique uses the CPM format which shows the inter-relationship between activities, this critical path is done after the fact and does not represent the real critical path at the time of the delay.

Further, claimants could tie delays to the critical path, and the delays which are their responsibilities might be shown, but hidden in the schedule and not tied to the critical path (Leary et al., 1988), This technique is not much better than the net impact technique except that the CPM format gives a more sophisticated presentation, but still it does not scrutinize the types of delays and does not determine the individual impact of each delay on the project completion date.

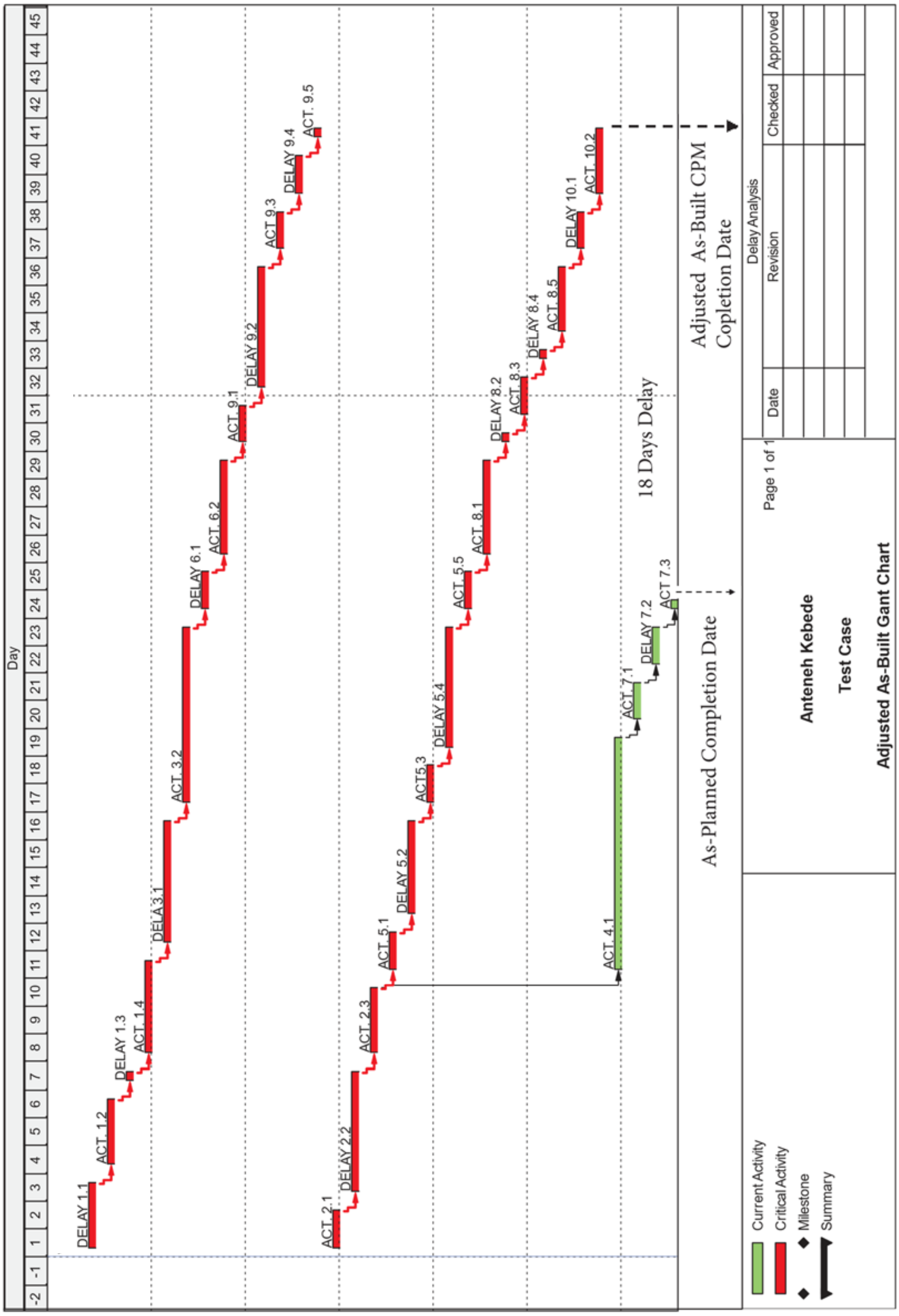

Fig. 8: Adjusted As-Built CPM Technique

2.12.3.4 But for (Collapse) Analysis

The as-planned schedule was used as a starting point, and only the delays for which the claimant is willing to accept responsibility were incorporated in the schedule inorder to recalculate the project completion date. The difference between the as-built completion date and the calculated completion date is the time for which the claimant is entitled to.
The technique was applied from both the owner's, and the contractor's point of view.

i) But for Contractor's Delays; Owner's Point of View

In performing the but for contractor's delays, only the delays which the owner is responsible for, i.e the excusable compensable and excusable non compensable were incorporated into the as-planned schedule to generate an adjusted completion date to the project. as shown Fig. 9 as a result this adjusted duration of the test case became 39 days. This indicates that but for contractor's delays the project would have been finished in 2 days less than the actual duration of 41 days. Thus, the contractor is responsible for 2 days delay for which the owner is entitled to compensation.

ii) But For Owner's Delays; Contractor's Point of View

Considering only the delays for which the contractor is responsible, i.e. nonexcusable delays were inserted into the as-planned schedule, as shown in fig. 10 The adjusted completion duration of the project resulted in 32 days, which is less than the as-built duration of 41 days, by 9 days. This discrepancy represents the time extension that the contractor is entitled to request for. The but for technique provides a better method for delay analysis since it addresses the issue of concurrent delays.

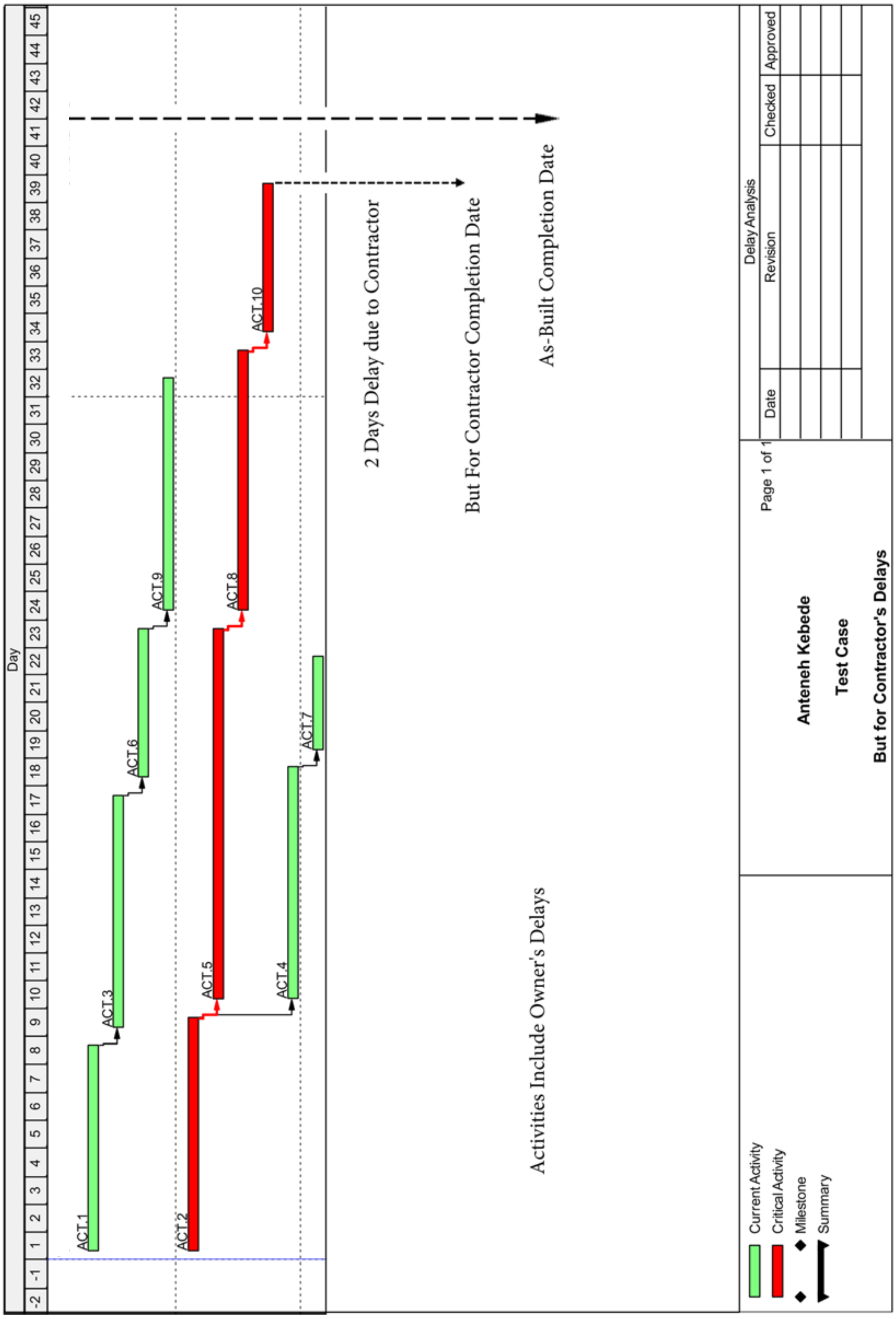

Fig. 9: But for Contractor’s Delays Technique

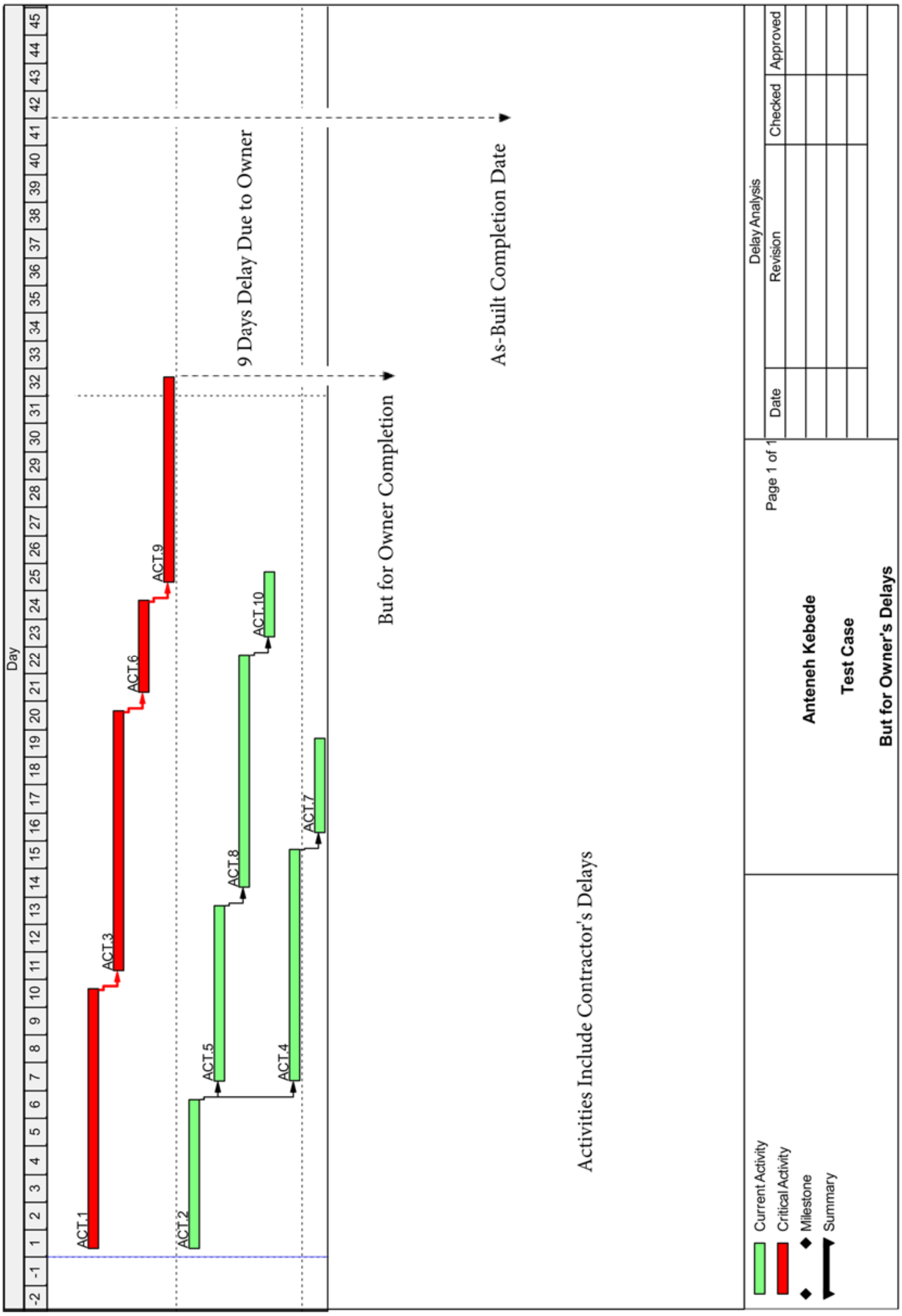

Fig. 10: But for Owner’s Delays Technique

Moreover, cause and effect relationships are not dealt with in the but for analysis, since delays are incorporated in one shot after the fact. In addition, the but for scrutinizes the types of delays and deals with the delays of each party independently, however this separation of analysis results lies in the fact that the critical path changes during the project and the delays which may be on the critical path of the actual schedule may not appear on the critical path of the adjusted schedule.
In the analysis done using the but for technique, the owner was found to be liable for 9 days, and the contractor for 2 days. Adding both parties' delays results in a total delay of 11 days.

2.12.3.5 Snapshot Analysis

Inorder to perform the snapshot technique to determine the impact of delays on the project completion date, two snapshot periods were imposed on the test case inorder to shorten the procedure, however the more periods one could provide, the more accurate results would be obtained. The first snapshot period, as shown in Fig. 11, was taken from the starting day till day 20 inclusive, where the day number is taken from the as-built schedule where all delays were identified in time duration. performing the first snapshot analysis, the as-planned schedule was used to start and all delays that occurred during the snapshot in consideration were incorporated into that schedule.

An as-built durations and logic of activities for the first snapshot period was established, while maintaining the rest of the schedule after that period as denoted in the as-planned schedule. The new project completion date was determined, and that adjusted duration of 34 days was compared to the as-planned duration of 23 days, resulting in a delay of 11 days due to the delaying events that occurred in the first snapshot period. This new schedule became the baseline schedule for the next snapshot analysis.

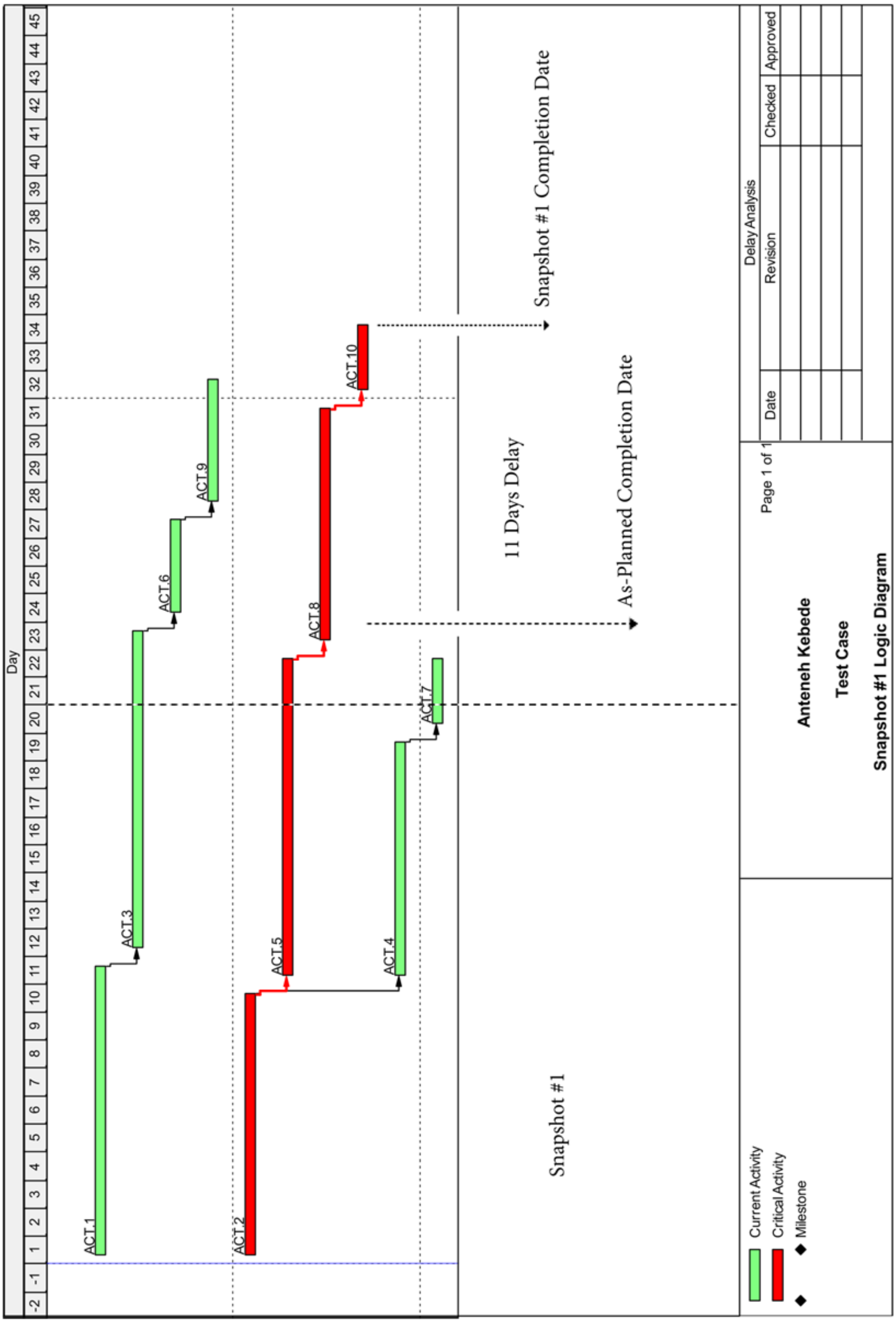

Fig. 11: Snapshot #1 Technique

For the second snapshot, that started from day 21 inclusive till day 41 or the end of project, the previous schedule of 34 days' duration that was performed in the first snapshot was used as a base. Delays that occurred in the second snapshot period, were inserted into the schedule as illustrated in Fig. 12. The new completion duration of the project for this snapshot period was 41 days, that is a delay of 7 days, by comparing 41 days to 34 days of the baseline schedule. In every snapshot period the comparison was done with the schedule determined in the previous snapshot period analysis.

To obtain the total overrun of the project duration, a summation of all the delays determined in each snapshot is required, that is adding 11 days and 7 days to get 18 days of total delay, which represents the total extended duration of the project. This amount of delay is the apportioned after an analysis inorder to determine the responsibility of each of the contractor and the owner.

The snapshot analysis offers some advantages over the other methods in the way it progresses with the schedule, since snapshots could be done as much as it is needed and a follow up of delays is performed thus a real critical path is determined at the time of the delay, thus taking into account the real effect of delays in time and context. This systematic and objective technique deals with problem of concurrency, and its accuracy depends on the number of snapshots performed, however it does not scrutinize the types of delays prior to the analysis, therefore, the results obtained require further complicated analysis to apportion the liabilities.

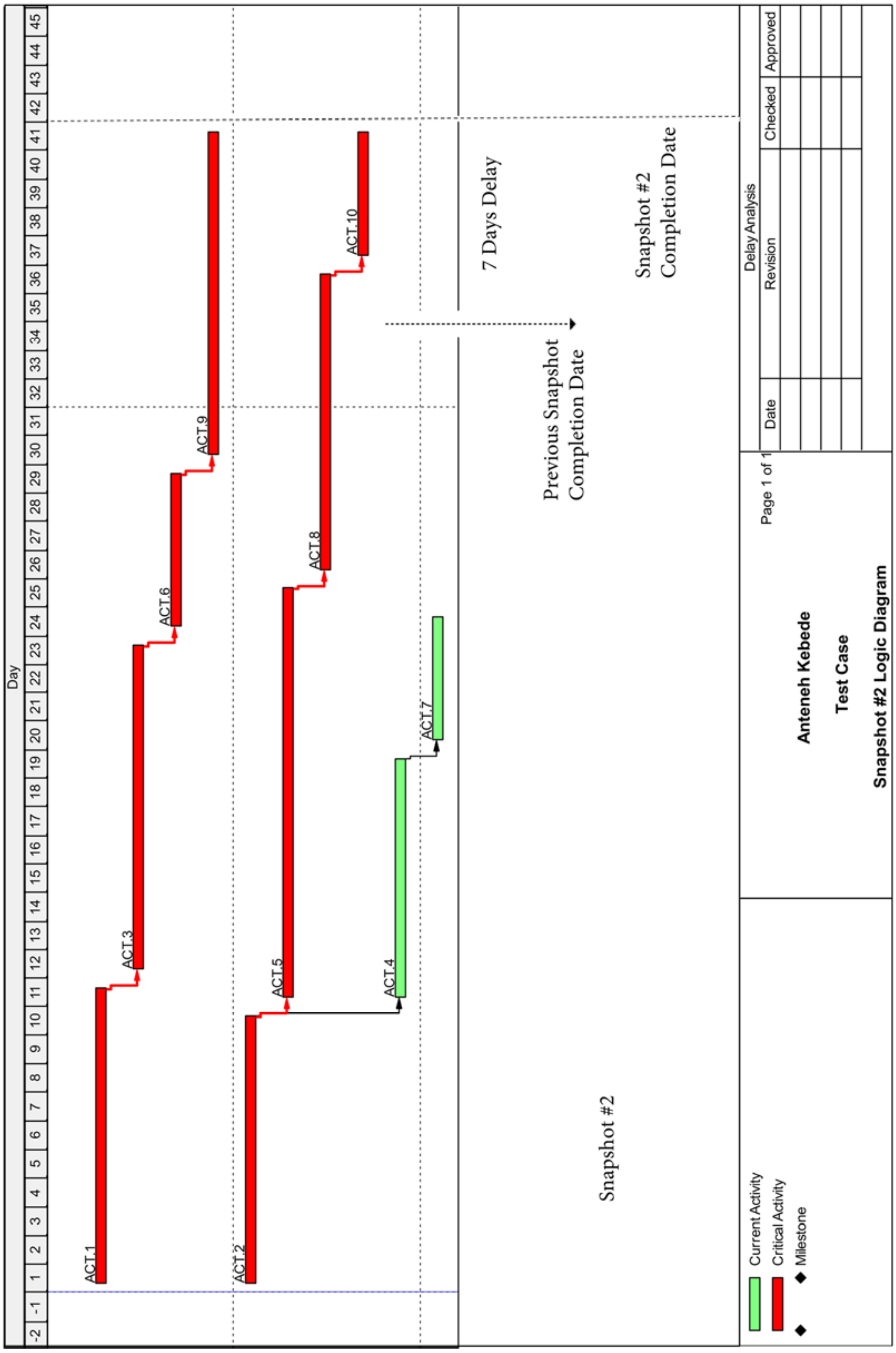

Fig. 12: Snapshot #2 Technique

2.12.3.6 Time Impact Analysis

The time impact is another way of examining periodically the effect of delays on the project. The analysis must be done to determine the effect that each delay had upon the schedule. The as-planned schedule should be updated at each major event or critical periods. In the test case under consideration delays were taken in each activity separately that is to say each delayed activity had been delayed by one major event.

The stop actions were chosen at the start of each activity and the delay was incorporated in that activity after which an adjusted schedule was determined and compared to the actual schedule frozen prior to the start of the activity in consideration. Fig. 13 represents the first time impact analysis. Starting with the as-planned schedule the first delayed activity was inserted into the schedule with its actual duration, and a new project duration was determined. The difference of time between this adjusted duration and the previous as-planned duration of 4 days is the delay due to the impact that occurred in activity 1.

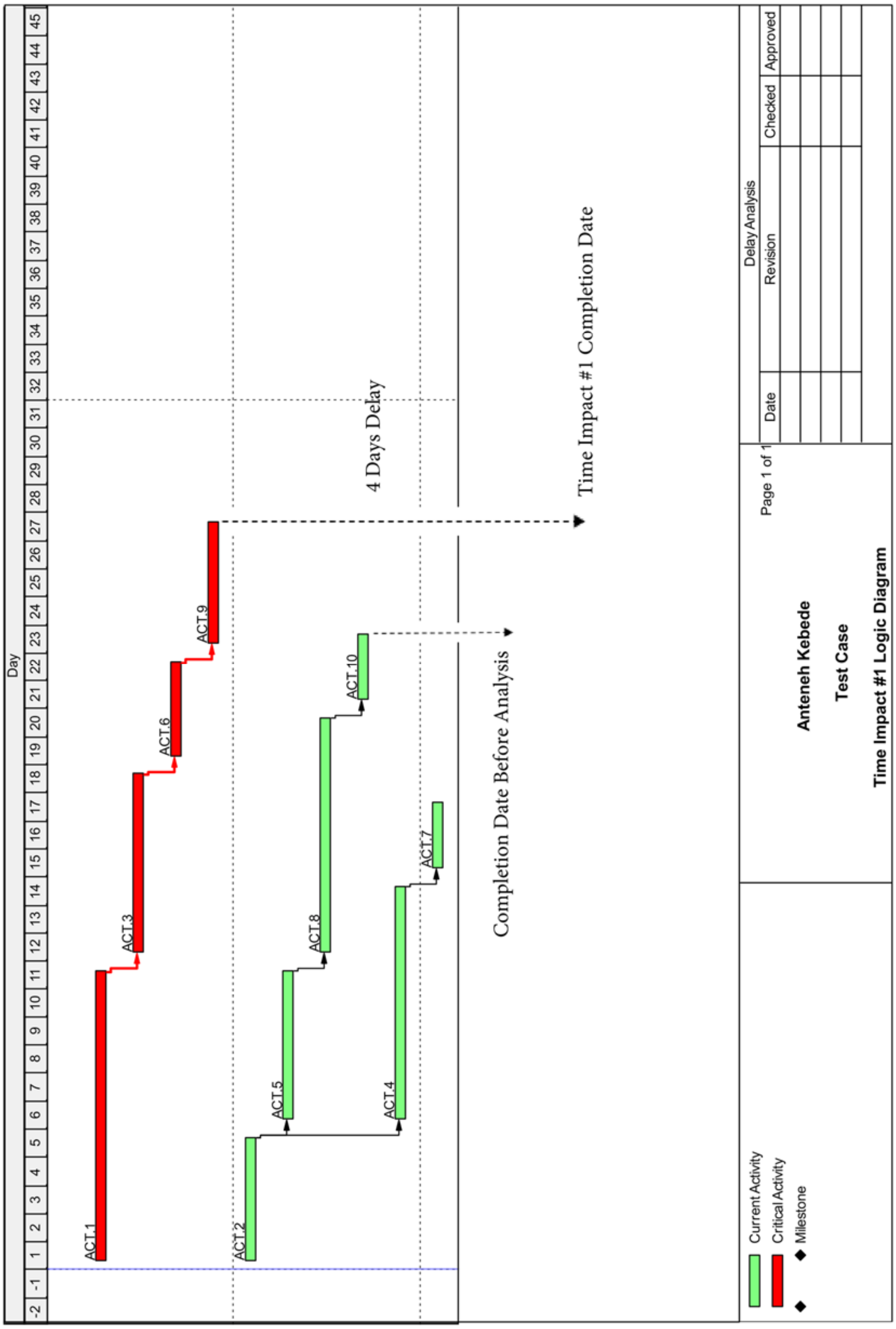

Fig. 13: Time Impact #1 Technique

The actual duration of activity 2, was incorporated into the as-planned schedule, for the second time impact analysis. After recalculation, the project completion date was extended by 5 days, as shown in Fig. 14.

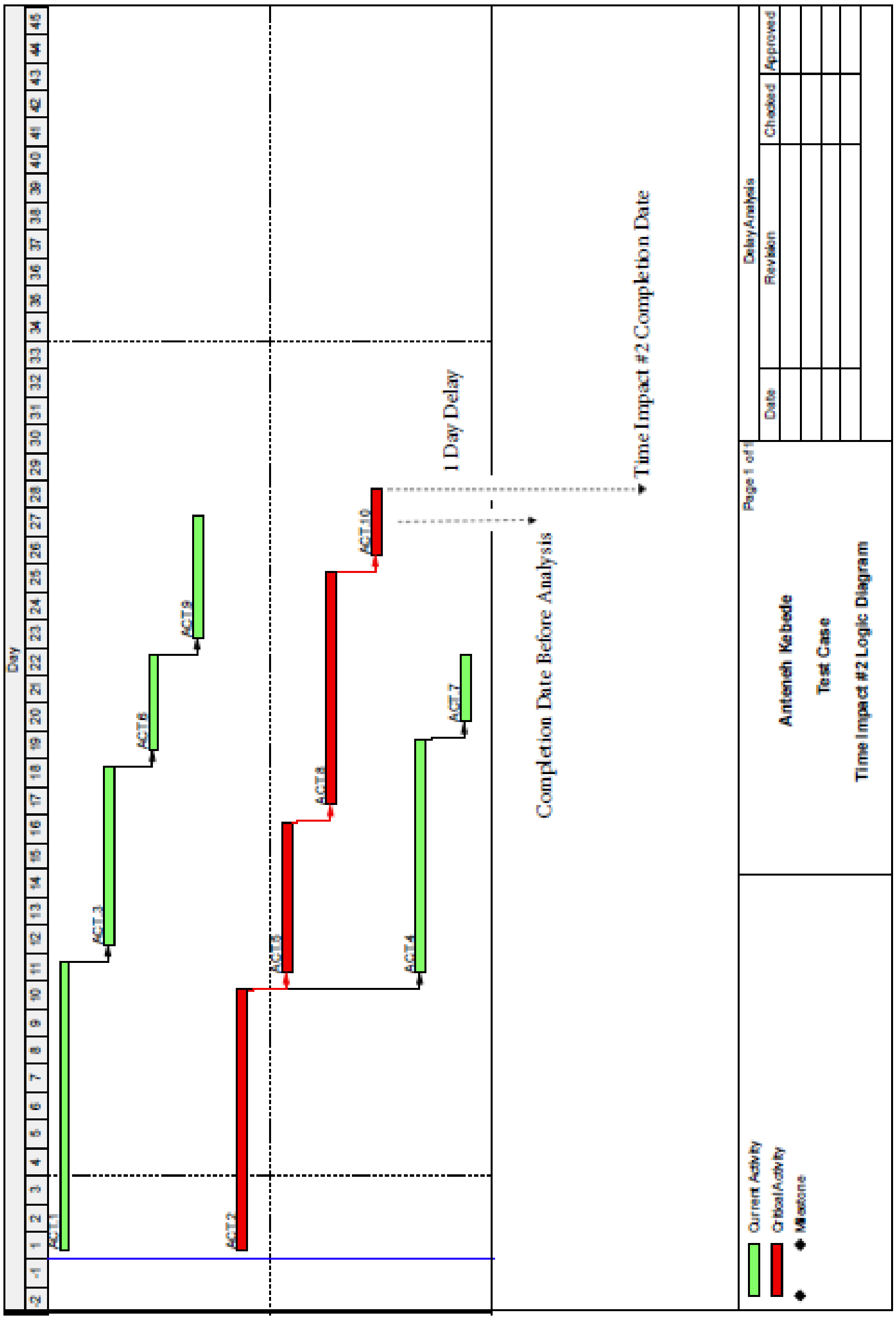

Fig. 14: Time Impact #2 Technique

The next activity to be analyzed was activity 3. Before inserting the actual duration of activity 3, the as-planned schedule was revised to reflect the actual schedule prior to the start of activity 3. A revised schedule was recalculated to determine the project's completion date. Then the actual duration of activity 3 was implemented in this revised schedule to determine an adjusted completion date, and the difference between the adjusted and the revised completion dates of 4 days, represents the amount of time the project had been delayed in accordance with the third time impact analysis, shown in Fig. 15.

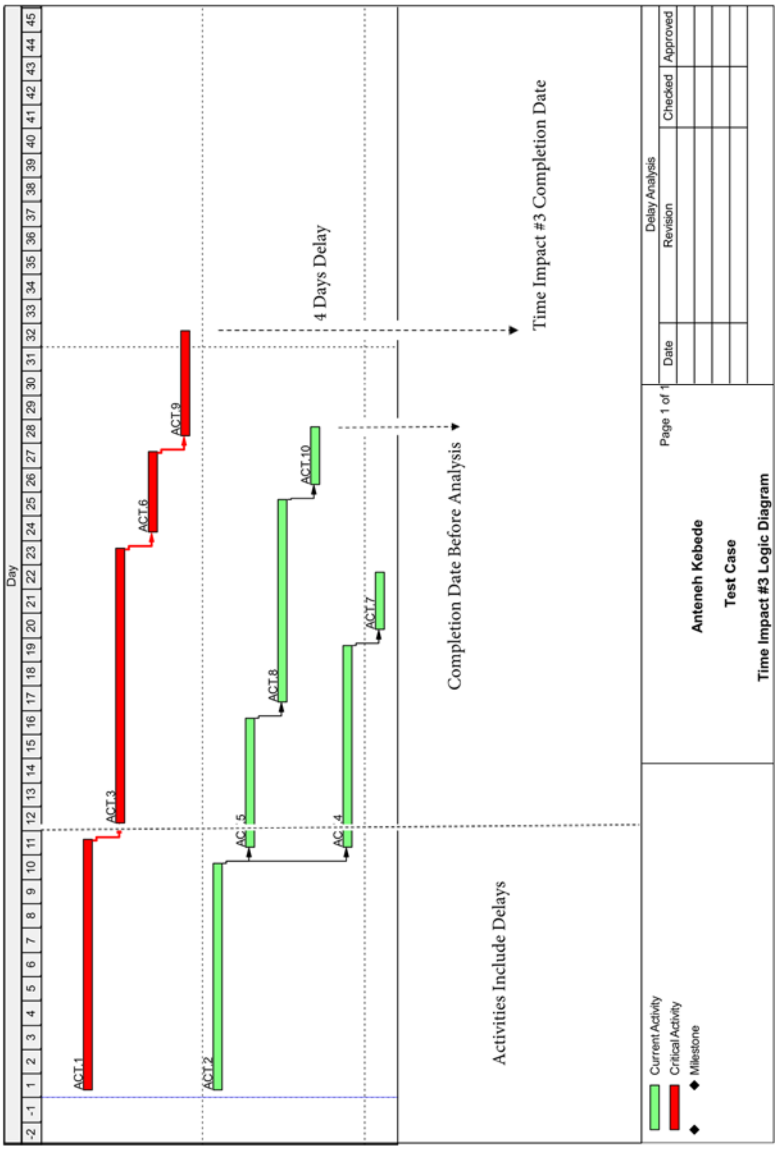

Fig. 15: Time Impact #3 Technique

The schedule is revised before the insertion of the delay on activity 5, and then a 9 days delay is incurred which pushes the completion date by 5 days at the end of time impact #4 as shown on Fig. 16.

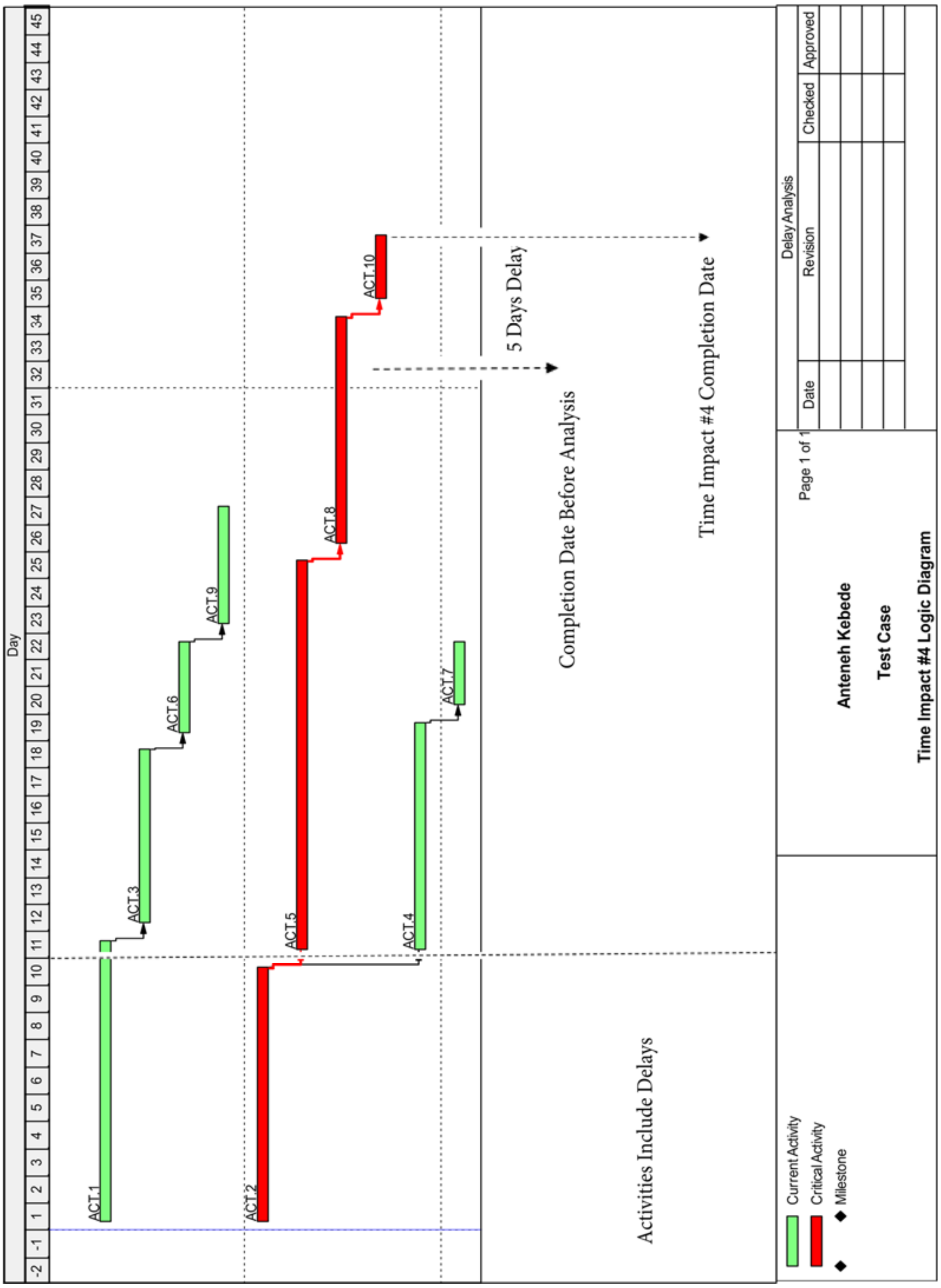

Fig. 16: Time Impact #4 Technique

The schedule is revised prior to the insertion of the delay on activity 6, then a 2 days delay is inserted on activity 6 but it does not affect the completion date at the end of time impact # 6 results in no delay as shown on Fig. 17

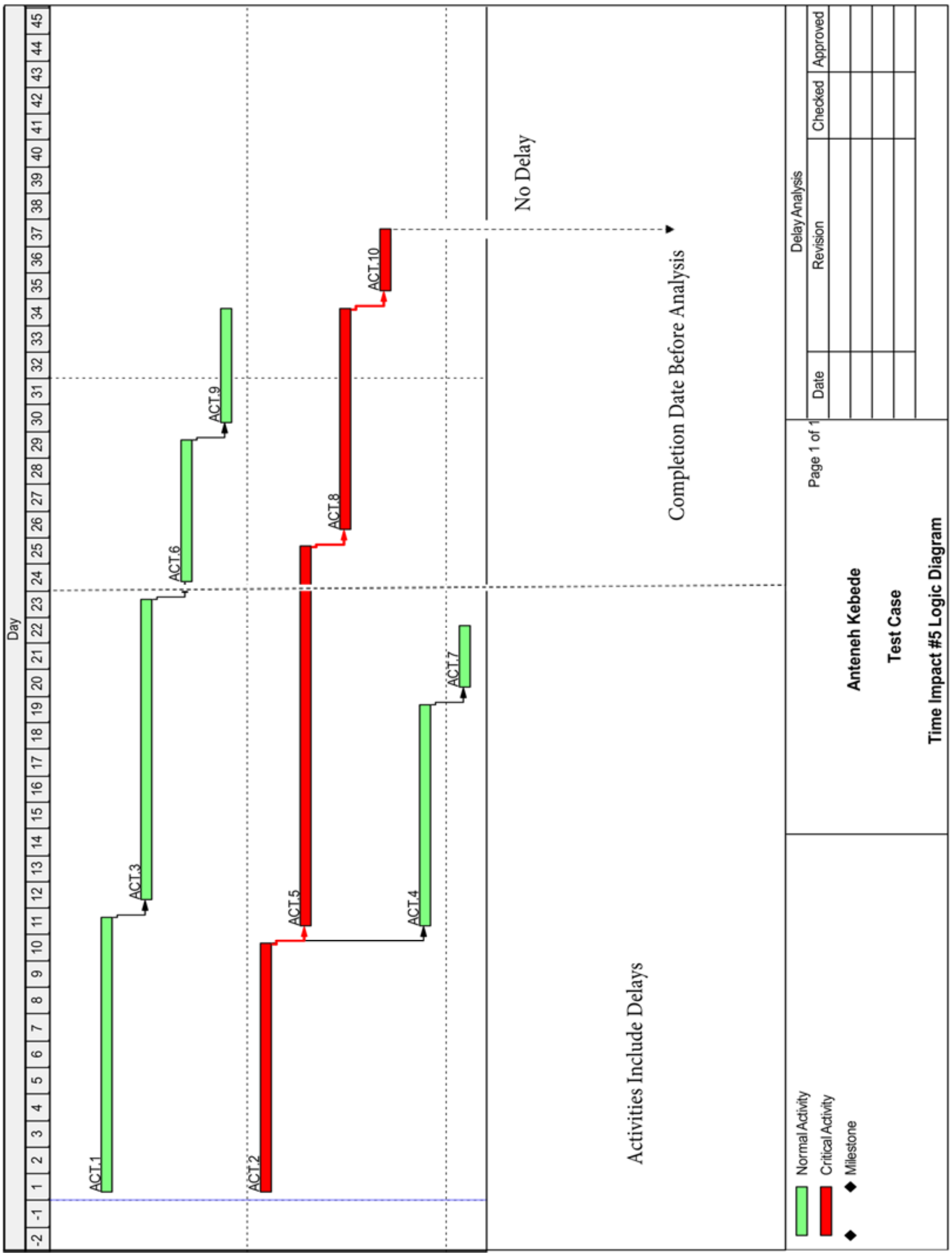

Fig. 17: Time Impact #5 Technique

The schedule is revised before the insertion of a delay on activity 7, then a 2 days delay is inserted to activity 7 but results in no delay because it has not pushed the revised completion date further, as shown in Fig. 18.

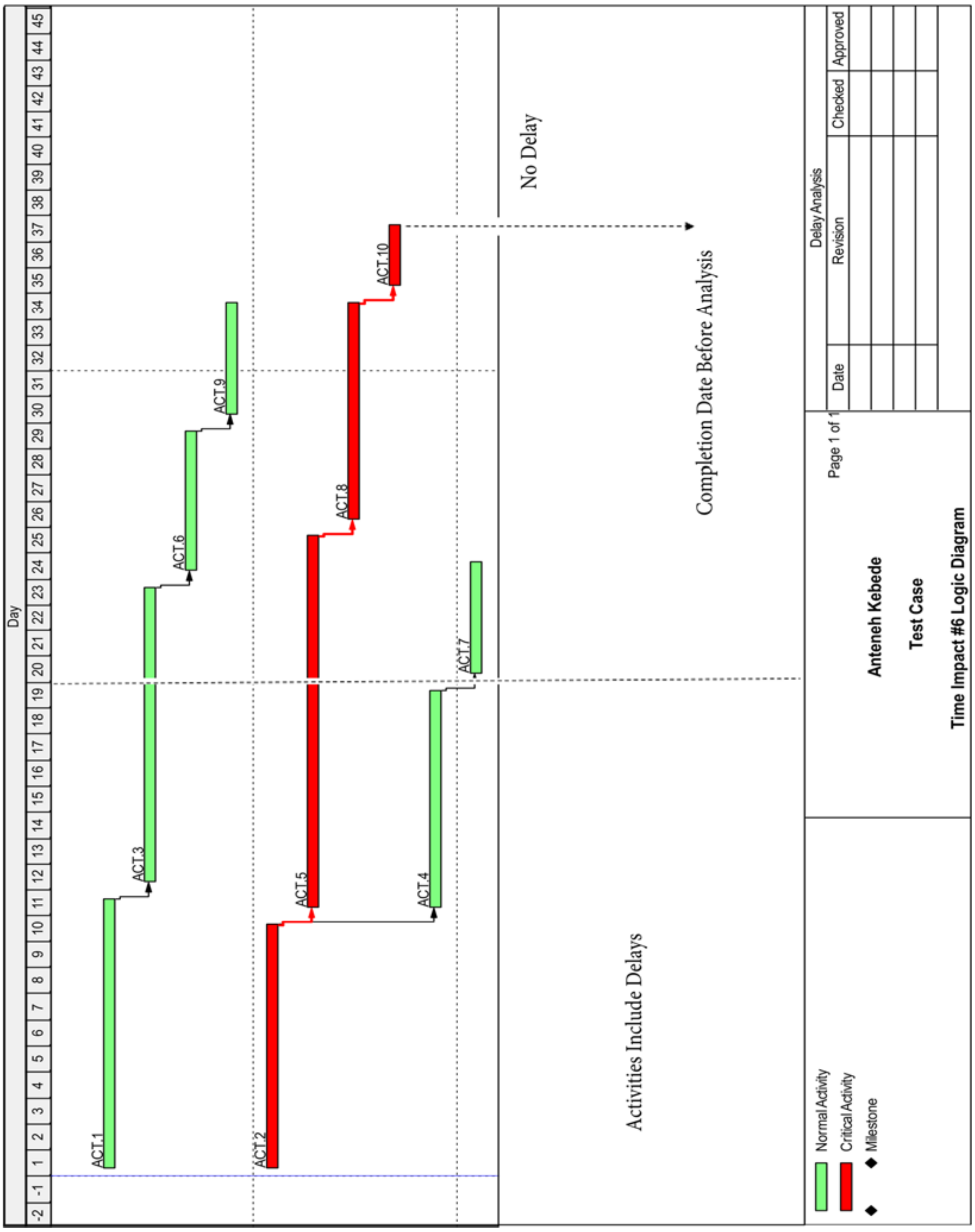

Fig. 18: Time Impact #6 Technique

The schedule is revised to reflect the actual situation prior to the insertion of delay, then a 2 days delay is inserted on activity 8 and results in a revised completion date, comparing it the date prior to the delay results in 2 days delay duration as shown on Fig. 19.

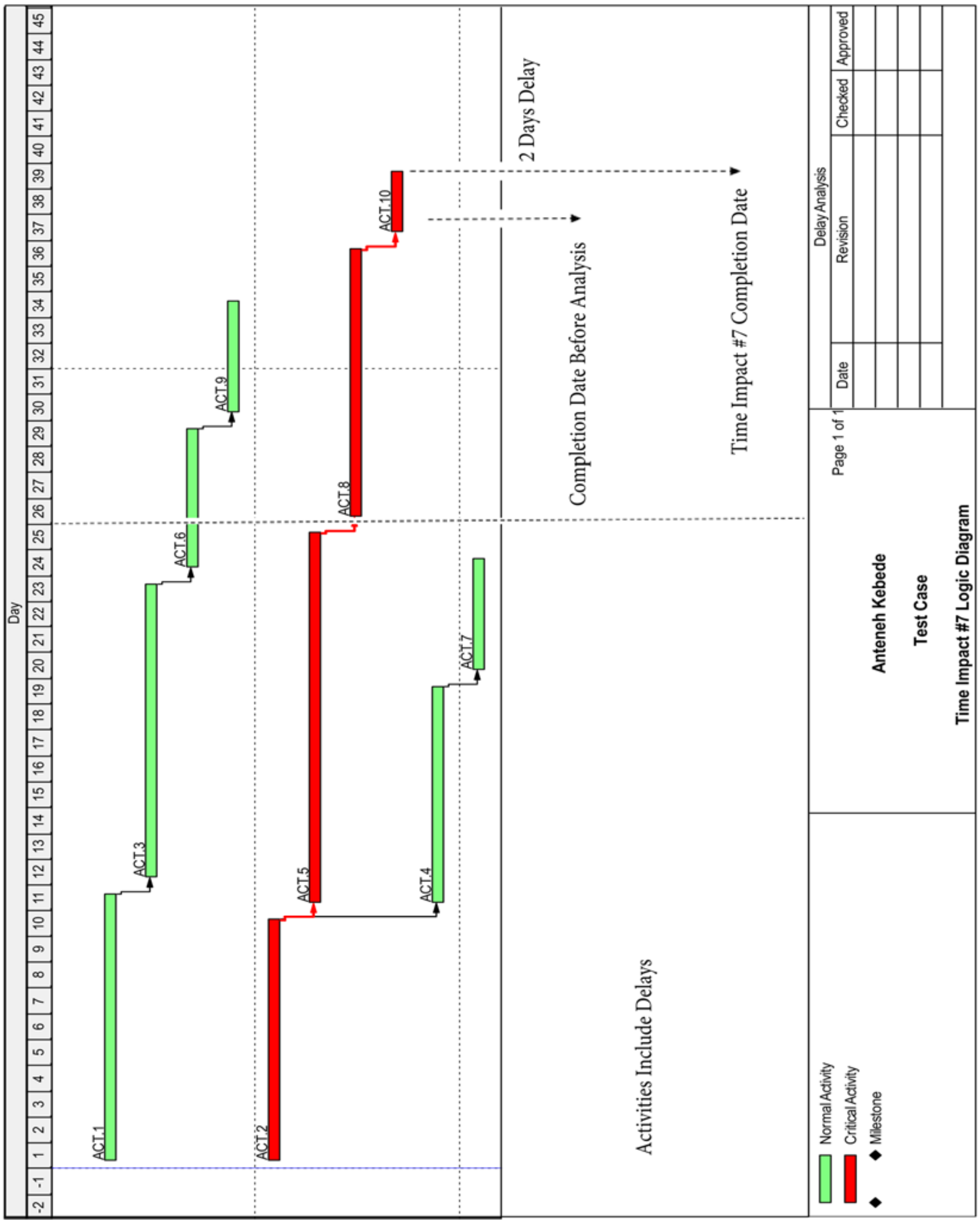

Fig. 19: Time Impact #7 Technique

Once again the schedule is revised prior to the insertion of a delay on activity 9, then a 9 days delay is inserted on activity 9 which pushes the revised completion date at the end of time impact #8 by 2 days more as shown on Fig. 20.

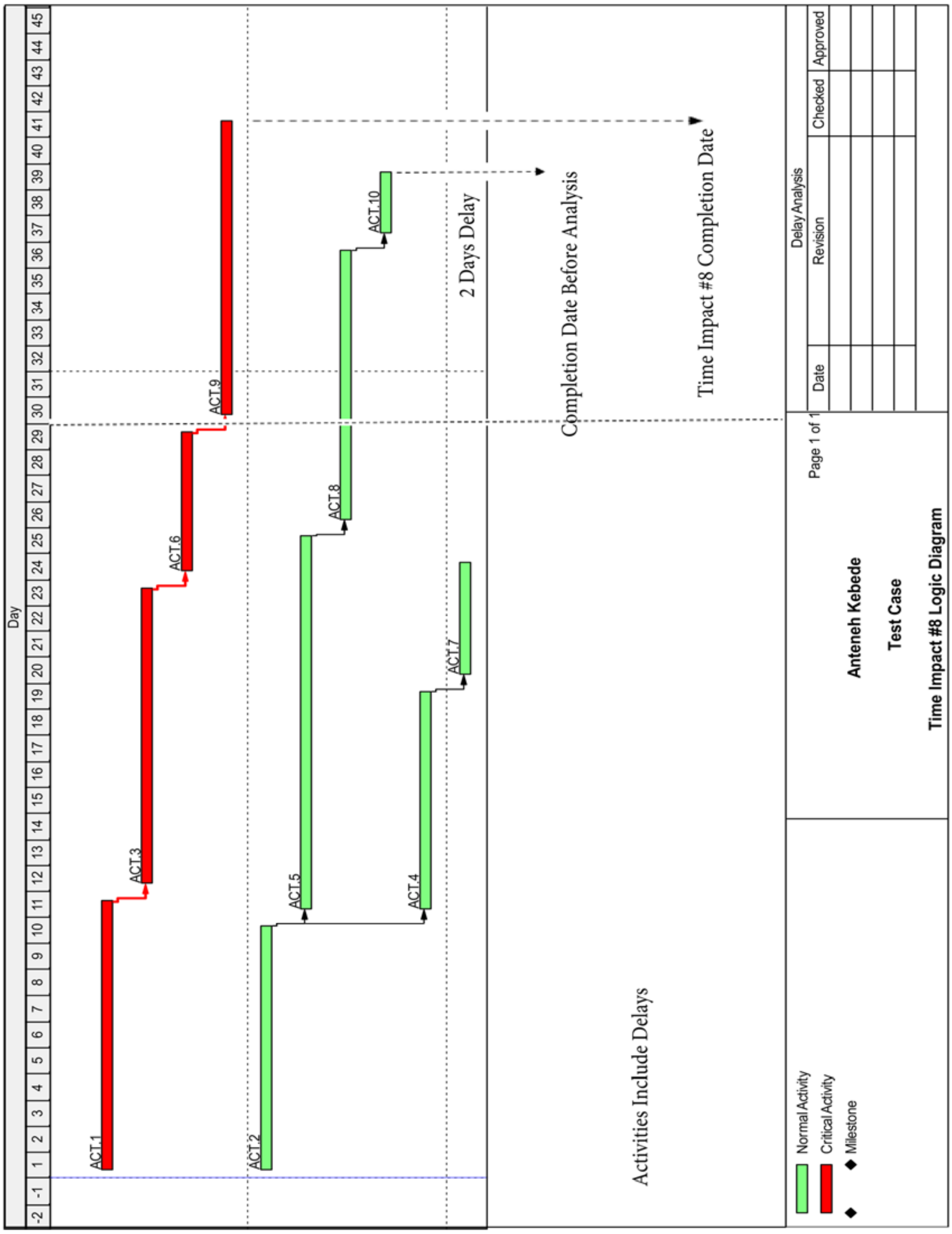

Fig. 20: Time Impact #8 Technique

Finally, the schedule is revised to reflect the real situation prior to the insertion of a delay on activity 10, then a 2 days delay is inserted to activity 10 which actually reaches at the same revised completion dates prior to the insertion of the delay and results in no delay as shown on Fig. 21.

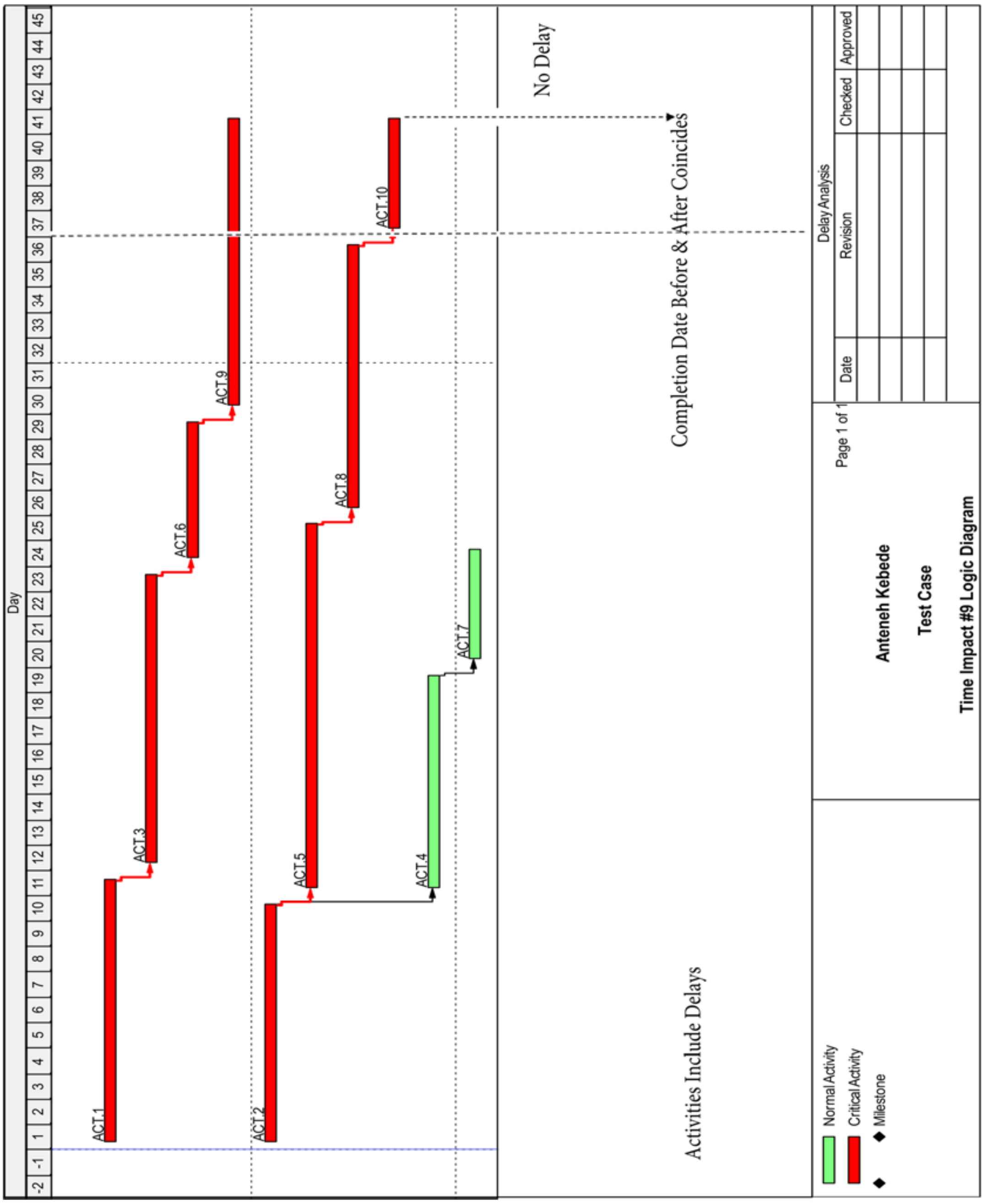

Fig. 21: Time Impact #9 Technique

Summing up all the delays determined in the nine analyses, a total of 18 days was obtained. This total amount of delay represents the total extended duration of the project, which should be further analyzed for apportionment of responsibility between the owner and the contractor.

The time impact technique provides a systematic and objective method of quantifying the impact of delays upon the project completion date. Since it analyzes the effect of delays in their context of time and critical path status. The goal of this technique is to measure the actual impact of delays on the project, individually or combined, and even with ongoing projects. However, this may become too cumbersome when there are an overwhelming amount of delaying events. Moreover, this technique does not scrutinize the types of delays prior to the analysis, therefore, further analysis is required for apportionment of responsibilities.

2.12.3.7 Isolated Delay Type Analysis

When applying the isolated delay type technique, each party's delays are analyzed separately. The contractor's delays are incorporated into the schedule to determine the basis for compensation entitled to the owner. The owner's fault delays, or the excusable compensable and noncompensable, when inserted into the schedule will allow to measure the amount of time that the contractor is entitled to. However, the quantification of compensable time is measured by including the excusable compensable delays into the schedule.

i) Isolated Delay Type; Contractor's Delays

For the test case under study, two time periods were defined for the isolated delay type technique. Starting with an as-planned schedule, only the nonexcusable delays related to the first time period which extended till the twentieth day, were inserted in the schedule.

This adjusted schedule duration of 29 days was compared with the as-planned duration of 23 days, and the 6 days difference represent the delays during the first time period that the contractor is responsible for, as shown in Fig. 22.

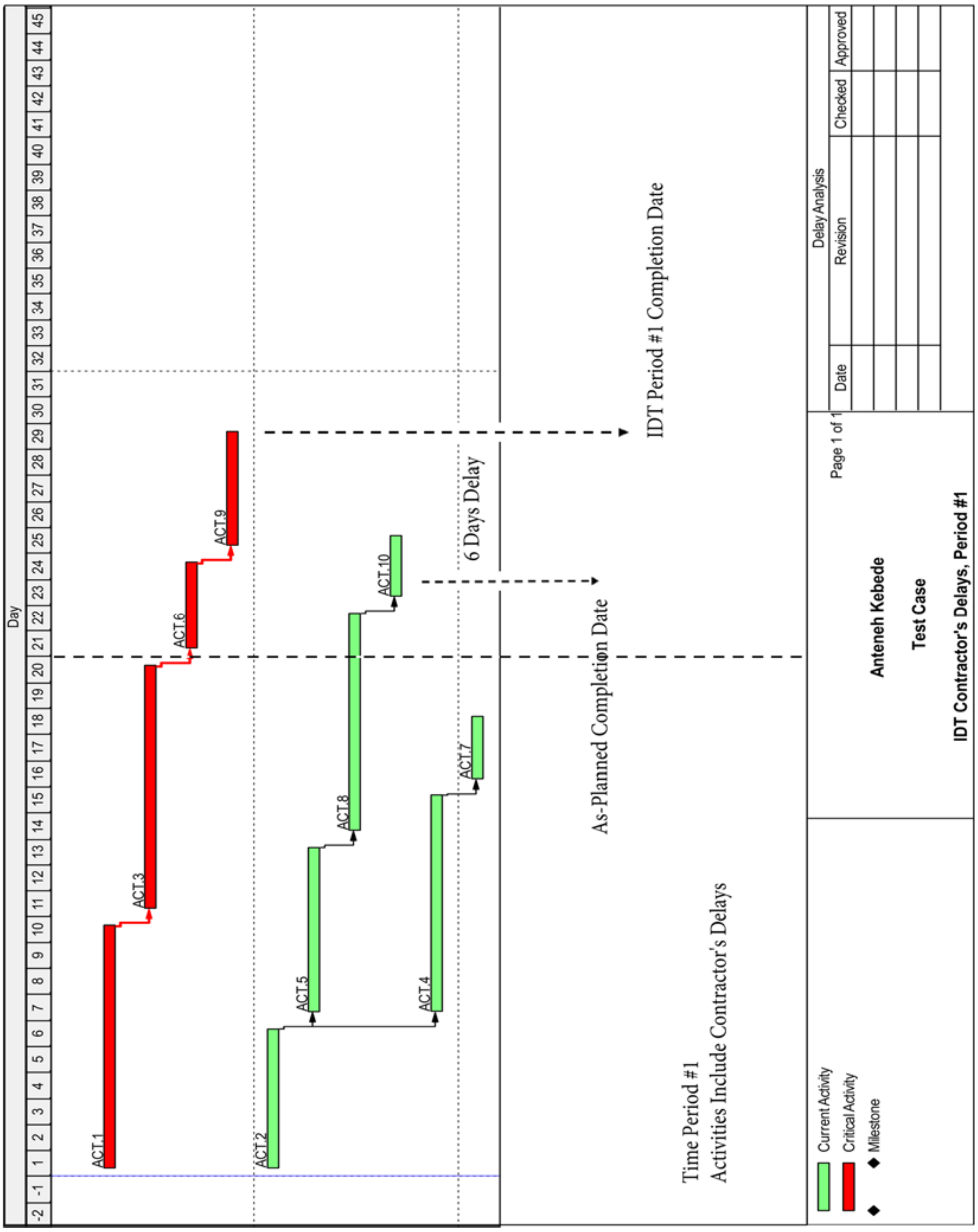

Fig. 22: Isolated Delay Type #1, Contractor's Delay

Similarly, for the second time periods which covered the rest of the schedule duration, the nonexcusable delays that occurred during that period were incorporated into the previous adjusted schedule of 29 days duration, and a new calculated schedule duration of 32 days was generated, as shown in Fig. 23. The discrepancy between the two schedules, which resulted in 3 days, is the amount of delay that the contractor is responsible for, during the second time period. Adding the results of both time periods, i.e. 6 and 3 days for the first and the second period respectively, gives a total of 9 days delay caused by the contractor.

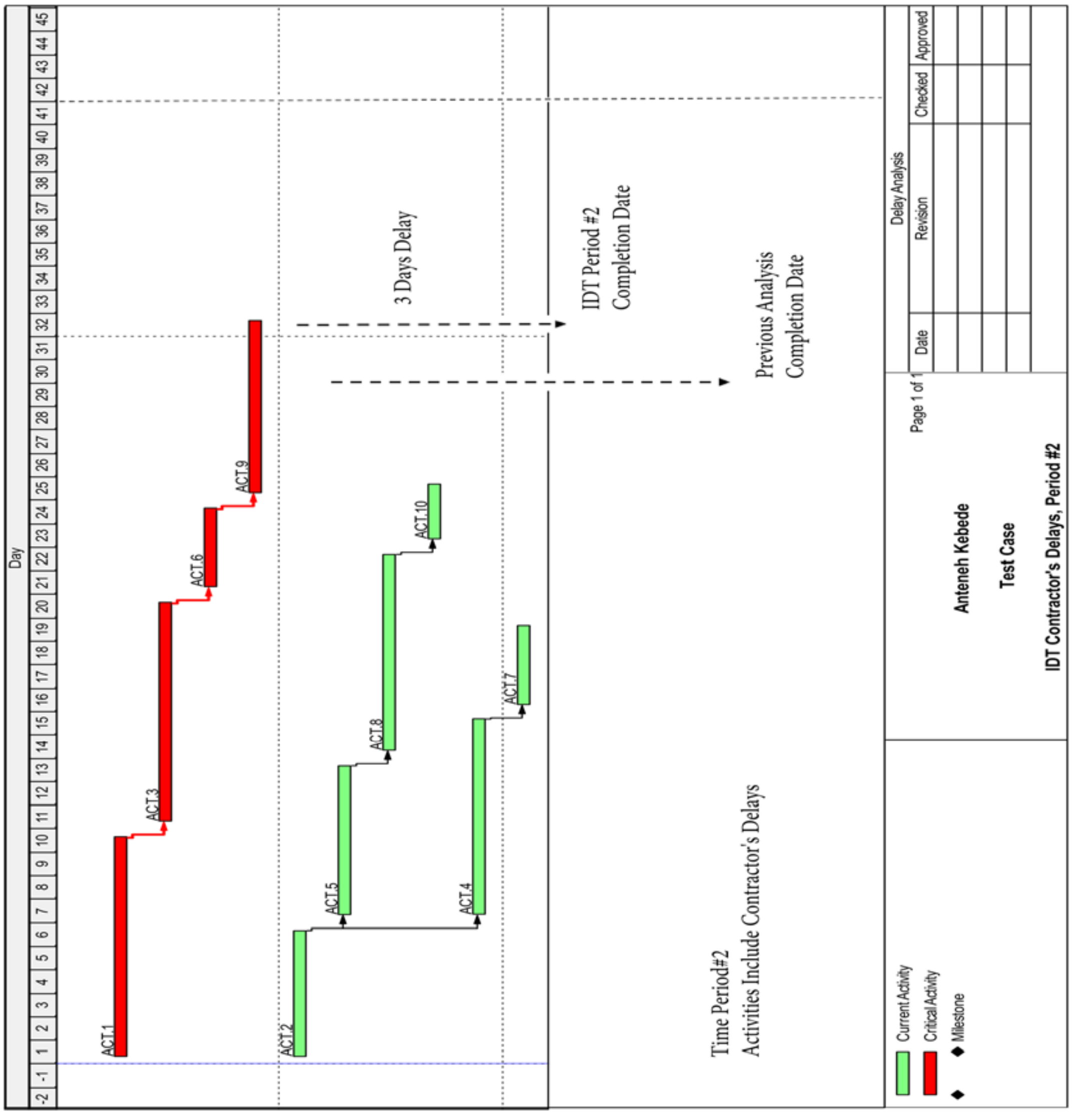

Fig. 23: Isolated Delay Type #2, Contractor’s Delay

ii) Isolated Delay Type; Owner's Delays

Regarding the delays caused by the owner, the excusable compensable and the excusable noncompensble delays related to the first time period, were incorporated into the as-planned schedule, and an adjusted schedule duration was determined, as shown in Fig. 24. The 32 days schedule duration was compared to the 23 days original duration, and the time variance of 9 days is attributed to the delays caused by the owner during the first time period.

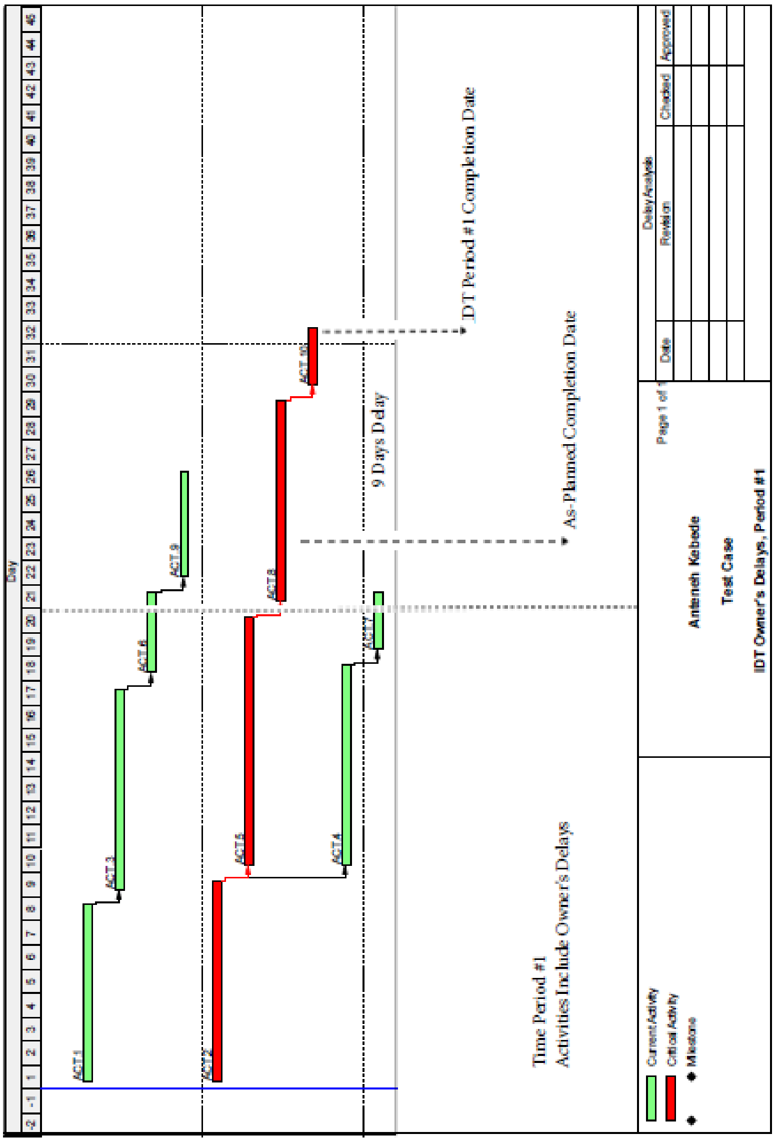

Fig. 24: Isolated Delay Type #1, Owner’s Delay

The previous schedule of 32 days duration was used for the basis of analysis in the second time period. Only the owner's fault delays, falling into the second period are included into that schedule, and the new schedule duration of 39 days was compared to the 32 days previous schedule duration, as shown in Fig. 25. The 7 days of difference between the schedules represents the amount of time that the contractor is entitled to extension of project duration during the second period.

The delays caused by the owner, i.e. the 9 and 7 days, for both time periods together, resulted in a total of 16 days delay due to the owner.

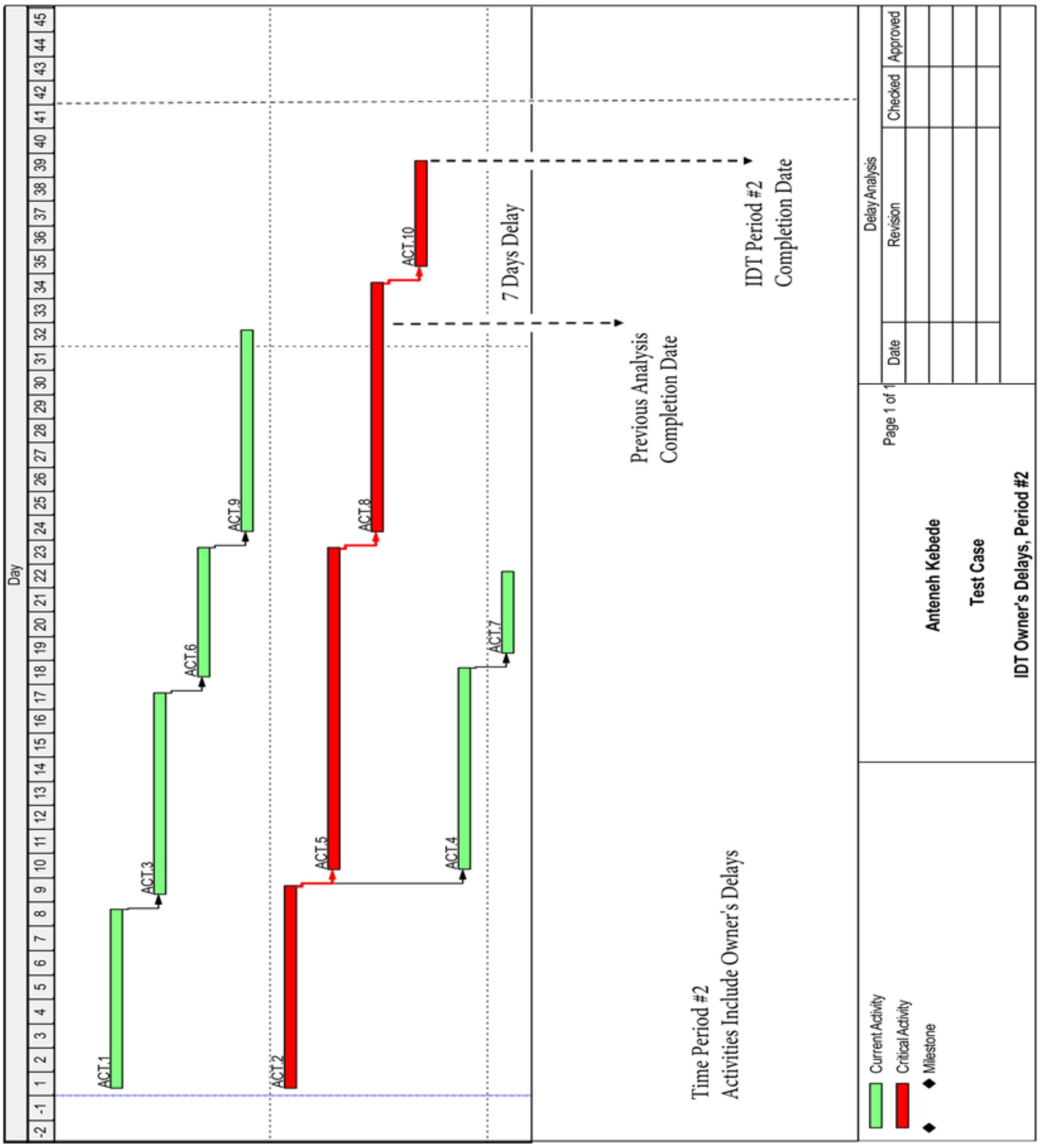

Fig. 25: Isolated Delay Type #2, Owner's Delay

The isolated delay type technique attempts to address the issue of scrutinizing delay types during the analysis, and the systematic approach by applying relevant time periods through the schedule. The analysis relies on an as-planned schedule to start the systematic analysis, and follow with the schedule comparisons, and each generated schedule becomes the basis for the following analysis.

2.12.4 Results of the Assessment

The following summarizes the results extracted from applying the current delay analysis technique to the test case under consideration:

Global Impact : 38 days
Net Impact: 18 days
Adjusted As-Built CPM: 18 days
But For Contractor's Delays: 2
But For Owner's Delays: 9 days
Snapshot: 18 days (to be apportioned between owner and contractor)
Time Impact: 18 Days (to be apportioned)
Isolated Delay Type, Contractor's Delays: 9 days
Isolated Delay Type, Owner's Delays: 16 days

Inorder to ensure the accuracy of a delay analysis, three main issues must be considered, these are: the right classification of delay types, the resolution of concurrency, and the analysis of delays in their real time and critical path. Without assessing the types of delays a wrong judgement for entitlement might occur. Concurrency or overlap of delays must be resolved inorder to avoid an overstatement of time extension requested for. It is important to ensure that the delays are analyzed using the actual critical path of the schedule since this path changes during the schedule analysis. Some delays might appear on a critical path in the adjusted schedule, while in the actual schedule they are not critical.

To summarize the advantages and disadvantages of these techniques, they were grouped into two levels of sophistication. The first being simplistic, which includes the global impact, net impact, and adjusted as-built CPM techniques. The second is detailed, which includes the but for, snapshot, time impact and isolated delay type. The detailed techniques are more reliable and preferred for preparing delay analyses, since they have more advantages than the simplistic techniques.

The major problem with the simplistic approach techniques is that they do not scrutinize delay types, as a result delays caused by one party might be considered the responsibility of the other party. These techniques are applied after the fact, which might be too late if damages need to be calculated during the project. In addition, the reliance on as - planned schedule generates another disadvantages, since it does not represent the real critical path, and could be unavailable at the time of the analysis. The global impact has an additional deficiency, which is the overstatement of total amount of delays, due to the problem of concurrency which is disregarded.

However, the systematic approach of the time impact, the snapshot, the isolated delay type, provide a dynamic analysis at the time of the delay, thus they are not performed after the fact.

CHAPTER THREE

RESEARCH METHODOLOGY

What factors affect the choice of one approach over another would be the research problem, the personal experience of the researcher, and the resources available largely determine the research design. (Gill and Johnson,2002; Creswell,2009).

The diversity of the research question & the scarcity of research on delay analysis techniques in Ethiopia dictates mixed method approach, a quantitative methodology of collecting data to address most of the 'what' question on the delay causing factors & assessment of the practice of the DATs followed by a qualitative method critical literature review of DATs to address most of the 'how' & 'why' questions. This kind of characteristics belongs to those determined by Creswell (2009) as requiring adoption of mixed methods research design approach.

Various research strategies have been considered such as experiments, survey, interview, archival analysis, and case studies. Archival analysis & case studies were discounted as unsuitable given the sensitivity & confidential nature of the subject matter, their application requires access to records of Delay Claims & disputes, which is unlikely that most companies will be willing to provide. Experiments & Interviews are field based requiring extensive time & cost to conduct than this research could afford. This approaches were discounted leaving survey the only appropriate option to rely upon.

There are two main types of surveys: cross-sectional and longitudinal studies. In a cross-sectional survey, data is collected on relevant variables at the same time or within a relatively short space of time. Longitudinal surveys on the other hand involve collecting data over long periods of time by taking measurements of the variables over two or more distinct periods. (Rea and Parker,1997). This type of survey was eliminated as inappropriate in the light of the time and resource constraints within which the research had to be completed, leaving cross-sectional survey as the most appropriate.

3.1 Design of the survey questionnaire

The researcher designed the research question in order to suite each contractor's project by stating the delay suffered by each one of them in order to receive a feedback that is reliable & truly happened on the project under consideration so that the respondents will give the right weighting having the picture of the project fresh in mind & the actual delay events occurred during construction.
The questionnaire survey anticipates to answer the 'what' and 'how' questions in exploring the current use of delay analysis techniques & the associated delay causing factors in Ethiopia. The survey is designed carefully to ensure that it elicits useful responses to these questions.
This will be achieved by following recommended best practice that includes making sure the questionnaire is easy to read and understand, as short as possible and capable of completing within a matter of minutes, and organised to flow smoothly without any hidden bias. Also, the wording of the questions will be carefully considered to prevent as much as possible any confusion or ambiguity.

In view of the nature of feedbacks being solicited, it will resolve that the questionnaire is designed to contain both open-ended and closed-ended questions.
Each of these formats has distinct advantages and disadvantage so combining them was essential in reducing or eliminating the disadvantages of each whilst gaining their advantages. The answers for the structured part of the questionnaire are based on Likert's scale of ordinal measure of agreement towards each statement.

3.2 Sampling Technique

The data collection was done by means of questionnaire and completed by randomly chosen 7 consultants who has got a substantial work contract with ERA & 5 contractors selected on the basis of purposive critical case sampling for they are underperforming as of ERA's September 2016 performance evaluation (Appendix B). According to (Ilker etal., 2016) The purposive sampling technique, is the deliberate choice of a participant due to the qualities the participant possesses in other words who knows most about the subject matter.

3.3 Data Collection

The questionnaires were addressed to the managing directors of the selected firms with an accompanying cover letter, explaining the purpose of the survey and asking that senior staff members with major involvement in claims preparation or assessment be encouraged to complete it.

The questionnaire is designed to produce answers to a number of questions pertinent to the research questions & objectives. This include the rating of existing delay analysis methodologies on a 5-point Likert scale in respect of: the extent of awareness, use and perceptions on reliability of these methodologies; the level of importance of a number of factors that influence the selection of delay analysis; and the frequency by which a number of factors have been obstacles to the use of these methodologies in practice.
The planning & programming issues associated with Delay Claims & the dominant delay causing factors have been rated on a 5-point Likert scale as well. This type of rating scale is recognised as the most appropriate for obtaining information about respondents' attitudes and perceptions or analysing particular attributes, as compared to asking a long list of individual questions (Rea and Parker, 1997).

Although the variables to be rated were identified from a thorough review on the body of literature on delay analysis, respondents were invited to add any other methodologies or factors that they consider were important but not included in the questionnaire.

3.4 Data Analysis

The data obtained from the survey were ordinal in nature as most of the responses were ratings measured on the Likert scale. Such data cannot be treated using parametric statistics methods unless precarious and, perhaps, unrealistic assumptions are made about the underlying distributions (Siegel and Castellan Jr., 1988). It was therefore found appropriate to analyse it using non-parametric statistics involving descriptive statistics analysis, relative index analysis, spearman rank order correlation, kendall coefficient of concordance and chi-square tests, factor analysis, and reliability analysis (using Cronbach's Alpha).

3.4.1 Descriptive Data Analysis

This involved the use of frequencies, percentages and means for presenting description finding of the survey. These techniques were employed for analysing data related to the characteristics of the respondents, their organisations, and open ended questions/comments. They were also used for the initial analysis of rating score data of the various research variables. Graphical techniques utilised for presenting the results from these analyses include pie chart, bar chart and tables.

3.4.2 Relative Index Analysis

Kometa et al. (1994) used the Relative Importance Index (RII) method to determine the relative importance of the various causes of delays. The same method was adopted in this study. The five-point Likert scale ranged from 1 (very low importance) to 5 (very high importance) was adopted and transformed to relative importance indices (RII) for each factor as follows:

$$RII = \left[\sum_{i=1}^{i=5} w_i f_i\right] X \frac{100\%}{n} \qquad \text{-----------------------Eq 1}$$

where *fi* is the frequency of response; *wi* is the weight for each rating (given by rating in the measurement scale divided by number of points in it, which is 5 in this case); and *n* is the total number of responses.
The ranking index is labelled differently depending upon the context, e.g., "involvement index", "awareness index", "success index", and "importance index". The RII was used to rank (R) the different causes.

These rankings made it possible to cross compare the relative importance of the factors as perceived by the respondents.
Each individual cause's RII perceived by all respondents were used to assess the general and overall rankings in order to give an overall picture of the causes of construction delays.

The Likert Scale is an ordered, one-dimensional scale from which respondents choose one option that best aligns with their view. There are typically between four and seven options. Five is very common.

All options usually have labels, although sometimes only a few are offered and the others are implied. A common form is an assertion, with which the person may agree or disagree to varying degrees. In scoring, numbers are usually assigned to each option (such as 1 to 5).

Equivalent weighted average percentage of relative importance index (*ERII*) per category is calculated for the 5 major delay causing group factors using the below formula for ranking the group factors(Sindhu,2015).

$$ERII = \frac{\sum(Pn\ X\ RII)}{\sum Pn} \quad \text{------------------------Eq 2}$$

Where P_n is the priority weight of the study factor, RII the relative importance index. Then the data is ordered using the ERII and made convenient for the further factor analysis.

3.4.3 Kendall Coefficient of Concordance and Chi-Square Tests

Inorder to determine the degree of agreement among the respondents in their rankings Kendall's coefficient of concordance(W) was used. This coefficient provides a measure of agreement between respondents within a survey on a scale of 0 to 1, with "0" indicating no agreement and "1" indicating perfect agreement or concordance. Using the rankings by each correspondent, W was computed using Equation 3 below (Siegel and Castellan Jr.,1988)

$$W = \frac{12\Sigma R_i^2 - 3k^2 N(N+1)^2}{k^2(N^3 - N) - k\Sigma T_j} \quad \text{------------------------Eq 3}$$

Where $\sum R^2_i$ is the sum of the squared sums of ranks for each N objects being ranked; K is the no of sets of ranking (i.e. the no of respondents); T_j is the correction factor required for the j^{th} set of ranks for tied observations given by $T_j = \sum_{i=1}^{g_j}(t_i^3 - t_i)$, where t_i the no of tied ranks in the i^{th} grouping of ties, and g^j is the number of groups of ties in the j^{th} set of ranks.

To verify the degree of agreement did not occur by chance, the significance of W was tested, the null hypothesis being perfect disagreement. The chi-square($\chi 2$) approximation of the sampling distribution given by equation 4 with (N-1) degrees of freedom is used for testing this hypothesis at a given level, for N>7(Sigel & Castellan Jr.,1988) calculated $\chi 2$ value greater than its counterpart table value implies that the W was significant at the given level of significance and as such the null hypothesis is not supported and thus has to be rejected.

$$\chi 2 = K(N-1)W \quad \text{---------------------------------Eq 4}$$

3.4.4 Spearman Rank Order Correlation

Further analysis was performed to identify any relationship between “Awareness” and “Use” on the one hand and “Use” and “Success” rate associated with claims analyzed by the techniques on the other hand. This correlation was performed using spearman rank(Rho) order of correlation test, with the help of SPSS.

3.4.5 Factor Analysis

On the analysis of delay causing factors after the data is sorted based on the equivalent relative importance index(ERII) a factor analysis is conducted.
Principal Component Analysis was then employed to extract the five groups, to clarify the factor pattern as to ensure that each variable loads high on one group factor & minimal on other group factor, the variables are rotated using promax oblique rotation, this type of rotation is appropriate when the data set is large and when there exists correlation between the group factors(Andy, 2004).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

The survey employed a questionnaire in collecting data on delay analysis techniques & delay causing factors from both consulting & contractor organizations in the Ethiopian Road Construction Sectors administered under ERA.
Out of 16 questionnaires sent out to 7 purposely chosen contractors & 9 randomly chosen consultants a total of 12 were returned (5 from the contractor & 7 from the consultant).

4.2 Characteristics of the respondents and their organization

Tables 4 shows the distribution of profile of respondents' organizations in terms of type and size and their designations for the construction and consulting firms.

Table 4: Construction Organization Response

Type of Organization	**Percent**
Contractor(N=5)	42%
Consultant(N=7)	58%
Contractor's Annual Turn Over(ETB)	
< 100m ETB	20%
100 – 500m ETB	20%
500 – 1b ETB	40%
>1b ETB	20%

Respondent Designation

Planning	0%
Quantity Surveying	0%
Contract Management	64%
Site Management	9%
Office Engineer	9%
External Claim Consultant	0%
General Consultant	9%
Project Coordinator	9%

With regard to the size of organization all of the consultants' turnover lies in the 0-100 m ETB range, on the respondents' designation planning & quantity surveying are not found in both the consultant and contractor organizational structure but are covered by other professions; contract management is a dominant designation both in the consultant & contractor organizations.

Table 5 shows their experiences with regard to a number of relevant functions.

Table 5: Experience & Qualification of Respondents

Functions	**Years of Experience**					
	0	**1-5**	**6-10**	**11-20**	**21-30**	**>31**
Estimating	2	5	4	1	0	0
Planning	5	5	2	0	0	0
Site Management	3	5	3	1	0	0
Measurement	5	6	1	0	0	0
Claim Preparation	0	7	5	0	0	0
Contract Management	0	3	6	1	1	1

Expert	Organisation	Designation	Department/Experise	Qualification	Years of Experience
1	Contractor	Project Manager	Site Management	BSc	21
2	Contractor	Senior Office Engineer	Technical Office	BSc	10
3	Contractor	Claims Expert	Contract Manager	BSc	15
4	Contractor	Contract Manager	Technical Office	MSc Cotm	12
5	Contractor	Manager	Engineering & Construction	MSc Cotm	26
6	Consultant	Resident Engineer	Supervision	MSc Cotm	15
7	Consultant	Project Coordinator	General Consultant	MSc Cotm	15
8	Consultant	Claims Expert	Procurement/Contract Management	MSc Cotm	24
9	Consultant	Contract Manager	Resident Engineer	BSc	35
10	Consultant	Deputy Engineer's Representative	Supervision/Contract Management	BSc	13
11	Consultant	Contract Engineer	Contract Management	BSc	13
12	Consultant	Project Coordinator	Supervision	BSc	10

4.3 Involvement in Delay Claims preparation and assessment

The issues to be dealt with as far as the analysis of claims on delay are concerned are complex, requiring an understanding of contract law, contract forms, contract administration, project planning techniques, and how construction activity typically takes place. This multi-disciplinary nature suggests that a variety of people with various expertise would have to work together in a team to ensure adequate analysis and settlement of Delay Claims. Respondents were thus asked to rank the level of involvement of relevant experts in their organisations in delay analysis on a five-point scale from "very low" (=1) to "very high" (5). Tables 6 and 7 give a summary of the results for construction and consulting firms, respectively.

Table 6: Level of involvement in Delay Claims of contractor staff

Expertise	Involvement Index	Rank
Head of Planning Department	90	1

Head of Quantity Surveying	80	2
Site Manager/Project Manager	80	3
External Claim Consultant	75	4

Within construction organisations, Head of Planning Department head scored the highest degree of involvement followed by Head of Quantity Surveying. This suggests that delay analysis is still the domain of planning engineers, with the development of user-friendly project planning software, programmers/schedulers appear to be making a significant contribution.

For consulting organisations, the external claim consultant scored the highest degree of Involvement. An issue of concern is that unless the claim expert is an in-house personnel (which is often not the case except perhaps in large organizations), there is the risk that enough time would not be available for claims assessment to be given the attention that it deserves.

Table 7: Level of involvement in Delay Claims of consultant staff

Expertise	**Involvement Index**	**Rank**
External Claim Consultant	74	1
Site Manager/Project Manager	71	2
Head of Planning Department	63	3
Head of Quantity Surveying	46	4

4.4 Timing of Delay Claims submissions and assessment

Timely submission of Delay Claims by contractors and their quick assessment by employers (or their representative) in the course of the project or as close in time to the occurrence of the delaying events is often recommended as a good practice.

The reason is that such practice ensures less difficult claims resolution because facts of the claims will be fresh in mind at that stage.

To investigate the extent to which this practice is observed by contracting parties, respondents were asked to score their level of agreement with the proposition: "the analysis and resolution of most Delay Claims are left unresolved until nearer the end of the project or after completion before resolving"; using a 5-point Likert scale (where '1= strongly disagree' to '5 =strongly agree').

Table 8 shows the results, which suggest that over 60% of the respondents from either construction or consulting firms are in agreement with this proposition.

Table 8: The proposition that most Delay Claims are resolved nearer project completions or after

Extent of Agreement	**Contractors**		**Consultants**	
Scale	**Percent**	**Cumulative%**	**Percent**	**Cumulative%**
Strongly Disagree	0	0	14	14
Disagree	0	0	0	14
Neutral	40	40	28	42
Agree	20	60	0	42
Strongly Agree	40	100	58	100

4.5 Extent of Disputes on Delay Claims

As mentioned earlier on, schedule delays are often recognised as a major source of disputes in the construction industry. To confirm the validity of this as a justification for the need to seek for improvement in current delay claim practice, respondents were asked to score their level of agreement with the proposition: *"the resolution of Delay Claims is often attended by considerable difficulties thereby causing disputes"*, using a 5-point Likert scale (where "1= strongly disagree" to "5 =strongly agree"). Table 9 shows the results, which suggest that over 60 percent of the contractor but less than 50% consultant respondents are of the opinion that Delay Claims often result in disputes.

This implies that Delay Claims resolutions continue to pose great challenge for contractors. Thus, there is still much to do in this subject area before matters of project Delay Claims can be resolved without much dispute.

Table 9: The proposition that most Delay Claims resolutions results in disputes

Extent of agreement Scale	**Construction**		**Consulting**	
	Percent	**Cumulative Percent**	**Percent**	**Cumulative Percent**
Strongly Disagree	0	0	14	14
Disagree	20	20	28	42
Neutral	20	40	14	56
Agree	40	80	28	84
Strongly Agree	20	100	16	100

4.6 Reasons for disputes over Delay Claims

An important consideration for improving delay analysis is identifying the reasons that often cause disputes over Delay Claims. In this respect, respondents were asked to rate the frequency by which a number of reasons have each been the cause of disputes or unsatisfactory resolution of Delay Claims, using a five-point scale (where “1= not very frequent” to “5 =very frequent”). Participants were also asked to add to the list and rate any other reasons they consider important.
Table 10 shows a summary of the results.

Table 10: Reasons for dispute over Delay Claims

Reasons	**Contractors**		**Consultants**		**Overall**	
	Frequency Index	**Rank**	**Frequency Index**	**Rank**	**Frequency Index**	**Rank**
inadequate effort at	76	1	86	2	81	1

mitigation						
inadequate supporting documentation on quantum	64	3	89	1	76	2
lack of timely notice	76	1	74	3	75	3
inadequate/incorrect notice	52	5	63	4	57	4
failure to establish casual link	72	3	40	7	56	5
contractual provisions not properly identified to support claim	52	5	57	5	55	6
conflicting interpretation of contractual provisions	48	7	49	6	48	7

Test Statistics

Kendall's W = 0.315

$\chi2_{critical}$ (α=0.05) = 12.592; df = 6; $\chi2_{sample}$ = 22.679

As can be seen, the three most likely sources of disputes are: inadequate effort at mitigation, inadequate supporting documentation on quantum and lack of timely notice. These issues therefore require much attention in researches aimed at reducing disputes on Delay Claims.

4.7 Perceptions on Existing Delay Analysis

4.7.1 Level of awareness of the methods

An important consideration that can affect the use or implementation of any delay analysis methods is its level of awareness among practitioners. Respondents were thus first asked to rank their level of awareness of the various methods on a five-point scale from “unaware” (=1) to “very aware” (=5). Table 11 shows a summary of the results obtained.

S-curve technique has got the higher awareness, followed by Adjusted As-Built Technique in the contractors but for the consultant it is the Adjusted As-Built followed by S-Curve technique leading the list. On the overall score it is the Adjusted As-Built followed by S-Curve technique. The methodology with the lowest level of awareness is Snapshot followed by the But For(Collapse) Technique.

Table 11: Level of Awareness of the Methods

Technique	Contractors		Consultants		Overall	
	Awareness Index	Rank	Awarness Index	Rank	Awarness Index	Rank
Adjusted As-Built	73	1	88	1	81	1
S-curve	73	1	86	2	80	2
Net Impact	70	3	77	3	74	3
Time Impact	67	4	74	4	70	4
Global Impact	63	5	74	4	69	5
Isolated Delay Analysis	50	6	74	4	62	6
But For(Collapse)	43	8	51	7	47	7
Snapshot	47	7	46	8	46	8

Test Statistics

Kendall's W = 0.446

$\chi 2_{critical}$ (α =0.05) = 14.07; df = 7; $\chi 2_{sample}$ = 37.431

4.7.2 Extent of Use of the methods

To investigate the practical applications of the various delay analysis techniques, respondents were asked to rank the extent of use of the methods using the 5-point scale from “very low” (=1) to “very high” (=5). A summary of the results is presented in Table 12.

The Adjusted Asbuilt followed by Net Impact & Time Impact is the most widely used method among both contractors & consultants.

Table 12: Extent of Use of the Methods

Technique	**Contractors**		**Consultants**		**Overall**	
	Usage Index	**Rank**	**Usage Index**	**Rank**	**Usage Index**	**Rank**
Adjusted As-Built	72	1	86	1	79	1
Net Impact	60	2	71	2	66	2
Time Impact	52	3	66	3	59	3
S-curve	52	3	63	4	57	4
Global Impact	48	5	63	4	55	5
Isolated Delay Type	48	5	49	6	48	6
But For(Collapse)	40	7	31	7	36	7
Snapshot	32	8	31	7	32	8

Test Statistics

Kendall's W = 0.398

$\chi 2_{\text{critical}}$ (α =0.05) = 14.07; df = 7; $\chi 2_{\text{sample}}$ = 33.428

4.7.3 Reliability of the techniques in delay analysis

This section of the questionnaire sought to examine respondents' views on the reliability of the methodologies in terms of settlement of claims without disputes that require resolution by a third party. These were studied: rating the level of claims' success associated with using each of the methods by rating them on a 1-5 scale (1 representing "very low" and 5 is for "very high").

Tables 13 summarizes the results.

Table 13: Level of Success with Delay Claims using the techniques

Technique	Contractors		Consultants		Overall	
	Success Index	Rank	Success Index	Rank	Success Index	Rank
Time Impact	85	1	69	2	77	1
Adjusted As-Built	70	2	83	1	76	2
Net Impact	55	5	66	3	60	3
Isolated Delay Type	60	3	57	5	59	4
S-Curve	50	7	60	4	55	5
Global Impact	55	5	54	6	54	6
But For(Collapse)	60	3	43	7	51	7
Snapshot	50	7	34	8	42	8

Test Statistics

Kendall's W = 0.376

$\chi2_{\text{critical}}$ (α =0.05) = 14.07; df = 7; $\chi2_{\text{sample}}$ = 28.918

Time Impact technique was ranked by contractors as the most effective in ensuring success of claims followed by Adjusted As-Built. This finding shows the fact that Time Impact, Adjusted As-Built and Net Impact are the top three most widely used methodologies, and are therefore likely to be the methods upon which most claims are finally resolved in Ethiopian road construction industry.

4.7.4 Correlation between DAT rankings

As a means of validating the ranking results, further investigation was carried out to identify any relationship between the ranking results of ‘awareness’ and ‘usage’ for each DAT on the one hand, and between ‘usage’ and ‘success’ rankings of the methodology on the other hand.

Spearman Rank Order Correlation test was employed in identifying any existing relationships as shown in Appendix E. A summary of the results obtained is shown in Table 14.

Table 14: Spearman Rank Order correlations on DATs rankings

Technique Attribute	**ρ(Rho) Correlation**	**Critical Value ρ**	**Significance for P<0.05**	**Reject/Accept the null hypothesis**
Awareness VS Usage	0.929	0.738	Significant	Reject
Usage VS Success	0.857	0.738	Significant	Reject

4.7.5 Factors influencing the selection of delay analysis techniques

As highlighted in Chapter 2, the factors that influence the selection of the appropriate methodologies are a matter of the greatest importance. Respondents were thus asked to rank a number of factors identified from literature, on a 5-point Likert scale (1 for “not important” and 5 for “very important”) on their degree of importance in their decision-making in delay analysis technique selection.

The results, shown in Table 15, demonstrate that on the whole “skills of the analyst” ranks first followed by “records availability”, while “the size of the project” and “the cost of using the technique” comes at the bottom.

The skills of the analyst as a number one rank confirms the notion that his experience, domain knowledge of the different DATs & his IT skills are of paramount importance in the DA. The ranking records availability as the second most important factor was not unexpected because irrespective of the method adopted, analysts will have to depend on the record for analysis, although the amount of records required varies for the various DATs.

Factors relating to the contract programme were generally ranked high by the consultants and overall, suggesting that programmes have relatively high degree of influence on the method selected for DA. This was not surprising as programmes are now recognised as the main vehicle for analysing.

Table 15: Relative Importance of Delay Analysis Selection Factors

Selection Factor	**Contractors**		**Consultants**		**Overall**	
	Importance Index	**Rank**	**Importance Index**	**Rank**	**Importance Index**	**Rank**
Skills of the analyst	100	1	97	3	99	1
Records availability	92	3	100	1	96	2

Baseline program availability	88	5	100	1	94	3
Reasons for the delay Analysis	96	2	89	5	92	4
Availability of updat ed Program	84	6	94	4	89	5
Nature of the delay ing event	92	4	86	6	89	6
Number of delays Requiring analysis	80	7	83	7	81	7
The complexity of The project	76	9	77	8	76	8
The stage of the project	76	8	74	9	75	9
The type of contract	72	10	74	9	73	10
The duration of the Project	60	11	54	12	57	11
The size of the Project	52	12	60	11	56	12
The cost of using The technique	52	12	43	13	47	13

Test Statistics

Kendall's W = 0.535

$\chi 2_{\text{critical}}$ (α =0.05) = 21.026; df = 12; $\chi 2_{\text{sample}}$ = 77.094

4.7.6 Obstacles to the use of delay analysis methodologies

Some researchers have sought to explain the relatively low use of some techniques by pointing out perceived obstacles to their successful usage. To investigate the validity of these commentaries respondents were asked to score the perceived obstacles on the frequency with which they are encountered in practice on a 5-point Likert scale (where "1= not frequent" to "5 = most frequent").
Table 16 shows the rankings of the obstacles obtained from analysis of the results.

Table 16: Obstacles to the use of delay analysis technique

Factors	Contractors		Consultants		Over all	
	Frequency Index	Rank	Frequency Index	Rank	Frequency Index	Rank
Baseline programme without CPM network	84	1	94	1	89	1
Lack of adequate project Information	80	2	94	1	87	2
Poorly updated programmes	76	3	94	1	85	3
Unrealistic baseline programme	72	5	94	1	83	4
Lack of skills in using Technique	76	3	80	5	78	5
Lack of familiarity with the	72	5	77	6	75	6

Technique						
Lack of suitable programming software	68	7	60	9	64	7
High time consumption in using technique	60	8	63	8	61	8
Difficulty in using the technique	56	9	66	7	61	9
High cost involved in its use	48	10	34	10	41	10

Test Statistics

Kendall's W = 0.51

$\chi2_{critical}$ (α =0.05) = 16.919; df = 9; $\chi2_{sample}$ = 55.067

Baseline programme without CPM network

Most contractors plan and manage construction projects using program of works; the high ranking of this factor both in the contractor & consultant shows there is a deficiency in showing the critical path; possible explanations include that the CPM schedules are withheld from Delay Claims because they tend to contradict the contractor's claim.

Lack of adequate project information

The second highest rank given to this factor corroborates commentaries on the poor quality of project records and the difficulty they pose to achieving the standard of proof required of Delay Claims. Delay analysis carried out using any of the methods relies very much upon what actually happened on the project, which in turn requires the keeping of detailed site records. Lack of such records makes analysis very difficult as a result some delays are likely to be concealed and others may be distorted resulting in inaccuracies.

Poorly updated programmes

The ideal way of proving delays is to determine the effect of individual delays on project as at the time that they occurred. For this to be achievable, the schedule has to be maintained properly by updating it periodically to keep track of important information such as changes in the critical path, actual start and finish dates and percentage complete for each activity; reassessed activity durations; and logic changes from previous updates. The high ranking of lack of proper updated programme as 3rd by both contractors and consultants and confirms its prominence.

4.8 Delay Causing Factors

Based on the ranking, the top fifteen (15) most important factors causing delays were shown in Table 17 below:

Table 17: List of top fifteen (15) most important factors causing delays in Ethiopian Construction Projects

No	Top fifteen (15) most important factors causing schedule delays	Group of factor	RII	Rank
1	Shortage of equipment	Equipment Related	90	1
2	Ineffective project planning and scheduling	Contractor Related	86	2
3	Slow mobilization of equipment	Equipment Related	86	3
4	Poor site management and supervision	Contractor Related	80	4
5	Unexpected surface & subsurface conditions (such as soil, hw table)	External Related	80	5
6	Frequent equipment breakdowns	Equipment Related	80	6
7	Low efficiency of equipment	Equipment Related	80	7
8	Delay in providing services from utilities (such as water, electricity)	External Related	78	8
9	Equipment allocation problem	Equipment Related	78	9
10	Design changes by owner or his agent during construction	Design Related	74	10
11	Incompetent project team	Contractor Related	74	11
12	Unfavorable weather conditions	External Related	74	12
13	Poor communication and coordination with other parties	Contractor Related	72	13
14	Insufficient data collection and survey before design	Design Related	70	14
15	Inadequate project management assistance	Consultant Related	70	15

Based on the same ranking, the top ten (10) least important factors causing schedule delays were shown in Table 18 below:

Table 18: List of top ten (10) least important factors causing schedule delays in construction projects

No	Top ten (10) least important factors causing schedule delays	Group of factor	RII	Rank
1	Problem with neighbors	External Related	30	48
2	Frequent change of subcontractors	Contractor Related	38	47
3	Loss of time by traffic control and restriction at job site	External Related	40	46
4	Delay in performing final inspection and certification by a third party	External Related	42	45
5	Accidents during construction	External Related	42	44
6	Natural disasters (flood, hurricane, earthquake)	External Related	42	43
7	Conflict, war, and public enemy	External Related	44	42
8	Changes in government regulations and laws	External Related	44	41
9	Global financial crisis	External Related	46	40
10	Delay in obtaining permits from municipality	External Related	50	39

Using the equivalent weighted average percentage, the ranking for each group factors category is computed as shown on Table 19.

Table 19: ERII ranking of the groups of factors of schedule delay

Group Of Factors	ERII	Rank
Equipment Related Factors	71	1
Contractor Related Factors	59	2
Consultant Related Factors	58	3
Design Related Factors	58	4
External Related Factors	44	5

4.8.1 Application of Factor Analysis to the selected factors

Table 20 shows the result of the factor analysis in a rotated structure matrix. The five groups account for 83.53% of the common variance by all 48 delay causing factors. The group factors were appraised to identify the underlying feature that constituent the delay causing factors have in common; and are arranged based on their percent variance: -

Group Factor 1 – Consultant Related Factors
Group Factor 2 – Contractor Related Factors
Group Factor 3 – Equipment Related Factors
Group Factor 4 – Design Related Factors
Group Factor 5 – External Related Factors

4.8.2 Reliability Analysis

In order to ensure the reliability of the research instrument i.e. questionnaire for testing its credibility for getting the same result if a study of same nature is conducted; for this purpose, a Cronbach's Alpha α have been employed which is the most common measure of scale reliability(Andy,2004) with a cut-off point of 0.7 and above is considered a good measure of reliability, the reliability analysis for all the 48 delay causing factors resulted in an Alpha(α) value of 0.934 using SPSS(Appendix F)

Table 20: Principal Component Analysis – Promax Rotation

Groups of factors	Factors causing schedule delays	Component					Communalities
		Group Factor 1	Group Factor 2	Group Factor 3	Group Factor 4	Group Factor 5	
Equipment Related Factors	Equipment allocation problem	-.837	-.254	**.201**	-.078	.111	0.839
	Frequent equipment breakdowns	-.026	.211	**.619**	.062	-.254	0.542
	Improper equipment	-.011	.454	**.519**	.000	.728	0.959
	Inadequate modern equipment	.634	.097	**.628**	-.445	-.273	0.961
	Low efficiency of equipment	.041	-.259	**.807**	-.067	.159	0.848
	Shortage of equipment	.752	-.132	**.145**	-.060	-.473	0.907
	Slow mobilization of equipment	-.188	-.127	**.818**	-.270	-.077	0.828
Contractor Related Factors	Frequent change of subcontractors	.521	**.602**	.539	.429	.498	0.934
	Inadequate contractor experience	.879	**.552**	.358	.342	.284	0.976
	Inappropriate construction methods	.833	**.724**	.223	.285	.261	0.941
	Incompetent project team	.915	**.254**	.408	.229	-.013	0.936
	Ineffective project planning and scheduling	.749	**.310**	.094	.548	-.406	0.973
	Obsolete technology	.041	**.152**	.180	.604	-.274	0.579
	Poor communication and coordination with other parties	.515	**.144**	.704	-.240	-.523	0.919
	Poor site management and supervision	.460	**.454**	.034	.144	-.752	0.987
	Rework due to errors	.284	**.740**	.324	.555	-.063	0.878
	Unreliable subcontractors	.321	**.902**	.357	.332	.122	0.927
Consultant Related Factors	Lack of experience of consultant in construction projects	**.739**	.611	.432	-.127	.290	0.918
	Conflicts between consultant and design engineer	**.848**	.408	.541	.074	.109	0.906
	Delay in approving major changes in the scope of work by consultant	**.478**	.302	.747	-.032	-.126	0.701
	Delay in performing inspection and testing	**.420**	.527	.662	.028	.052	0.665
	Inaccurate site investigation	**.023**	.586	.278	.218	.174	0.481
	Inadequate project management assistance	**.611**	.072	.281	-.487	-.152	0.741
	Late in reviewing and approving design documents	**.874**	.607	.397	-.075	-.013	0.948
	Poor communication and coordination with other parties	**.806**	.431	-.219	.243	-.003	0.816
Design Related Factors	Complexity of project design	.233	.944	.064	**.029**	.351	0.970
	Design changes by owner or his agent during construction	.471	.774	-.233	**.104**	.092	0.766
	Design errors made by designers	.674	.833	.010	**.127**	.071	0.862
	Insufficient data collection and survey before design	.364	.628	-.392	**.435**	.271	0.754
	Lack of experience of design team in construction projects	.567	.662	-.031	**.612**	.498	0.931
	Mistakes and delays in producing design documents	.830	.713	.018	**.291**	.095	0.904
	Misunderstanding of owner's requirements by design engineer	.776	.539	.023	**.472**	.135	0.798
	Poor use of advanced engineering design software	.511	.219	.354	**.733**	.272	0.853
	Unclear and inadequate details in drawings	.460	.847	.042	**.033**	-.081	0.798
External Related Factors	Accidents during construction	.620	.578	.196	.473	**-.356**	0.863
	Changes in government regulations and laws	.722	.053	-.076	.296	**-.297**	0.737
	Conflict, war, and public enemy	.236	.892	.101	.411	**.193**	0.889
	Delay in obtaining permits from municipality	-.648	-.465	-.306	.211	**.548**	0.882
	Delay in performing final inspection and certification by a third party	.201	.285	-.241	.743	**.698**	0.959
	Delay in providing services from utilities (such as water, electricity)	.736	.060	-.092	.338	**.391**	0.912
	Global financial crisis	.346	.287	-.100	.804	**.006**	0.740
	Loss of time by traffic control and restriction at job site	.185	.047	.654	.147	**.050**	0.471
	Natural disasters (flood, hurricane, earthquake)	.160	.397	.848	.251	**.242**	0.914
	Price fluctuations	.041	-.314	.705	.343	**-.231**	0.901
	Problem with neighbors	-.105	.252	.469	.511	**.290**	0.653
	Slow site clearance	.119	-.521	.297	.525	**-.211**	0.908
	Unexpected surface& subsurface conditions (such as soil, hw table)	.045	.485	-.039	-.052	**.661**	0.642
	Unfavorable weather conditions	.267	.332	.052	.091	**.873**	0.878
	Eigen Value	**16.98**	**7.41**	**6.72**	**4.66**	**4.33**	
	Percent Variance	**35.37**	**15.43**	**14.00**	**9.71**	**9.02**	
	Cumulative % Variance	**35.37**	**50.80**	**64.80**	**74.51**	**83.53**	

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This chapter has presented the results of a questionnaire survey of contractors and consultants aimed for establishing the current practice in the use of delay analysis techniques and their associated problem. The survey questionnaires were distributed to 16 construction organisations engaged in Ethiopian road construction and received an overall response rate of 75%, representing 5 responses from contractor organisation and 7 from consulting organisations. The respondents were mostly from medium to large construction organisations with considerable experience in claims evaluations.

Relative importance index was majorly used to analyse the survey data. There was a considerable corroboration between the study results and the findings of the literature review. A summary of the findings of the survey is as follows with respect to the research objective:

Investigation into the planning & programming issues associate with Delay Claims resolution: -

(a) The majority of the respondents agree that Delay Claims are often left unresolved until nearer the end of the project or after before resolving. Also, majority agree that Delay Claims resolutions are often attended by considerable difficulties resulting in frequent disputes.

(b) The main reasons for disputes over Delay Claims are inadequate effort at mitigation, inadequate supporting documentation on quantum and lack of timely notice suggesting that there are deficiencies in current mitigation & record keeping practice which require more attention. Other sources also indicate that the view towards claim in all the three parties (i.e. Contractor, Consultant, Client)

(c) The main obstacles to the use of DATs are lack of baseline program without CPM network, lack of adequate project information and poorly updated programmes, this supports the earlier finding from the literature that: poor baseline program, failure to update program, and inadequately updated programs are the major deficiencies in practice that affects smooth analysis and resolution of Delay Claims.

Assessment of the practice of delay analysis technique in the Ethiopian Road Construction Industry: -

(d) On the whole, the three most well-known methodologies for analysing Delay Claims are the Adjusted As-Built, S-curve and net impact method, whilst the least known are the snapshot, but for(collapse) and isolated delay analysis.

(e) A total of 13 selection criteria were identified as relevant in influencing the selection of delay analysis technique. These criteria have different rates of importance with the top five as skills of the analyst, records availability, baseline programme availability, reasons for the delay analysis and updated programme availability.

(f) The respondents employ the various delay analysis techniques to the same extent as they are aware of them at significant correlations (see Sections 4.7.4), The more detailed methods (i.e. Time Impact Analysis, Snapshot Analysis, But For, and Isolated Delay Type Techniques) are reported as being more accurate and reliable than the simplistic ones (i.e. Global method, Net Impact Technique and Adjusted As Built), although the former group requires more expense, time, skills, resources and project records to operate than the latter.

(g) On the methodologies for analysing Delay Claims, the most well-known and widely used methods are time impact, adjusted as-built and net impact. Although they are known to have strengths, the least used methodologies are snapshot, But For Collapse and S-curve.

Identifying the most prevalent delay causing factor in road projects administered under Ethiopian Roads Authority:

(h) The result of the survey for the most dominant delay causing factor resulted in shortage of equipment (RII = 90), Ineffective project planning and scheduling of the contractor (with RII=86) and slow mobilization of equipment (RII=86)

(i) On analysing the delay causing group factors using factor analysis resulted in Consultant Related Factors, Contractor Related Factors, Equipment Related Factors, Design Related Factors, and External Related Factors from highest to lowest loading.

In conclusion, the main difficulties with Delay Claim resolutions and the ensuing disputes are due to poor programming practices and record keeping which have led to less accurate and challenging claims results.

5.2 Recommendations

Problems related to programming and record keeping practice has made the use of more accurate methodologies less amenable as they require detailed and accurate programmes and project records to implement. To facilitate their use, thereby helping to reduce or avoid disputes, the following recommendations are suggested.

1 Immediate assessment of Delay Claims depicting their time impact on the POW at the time they occur using contemporaneous techniques would help the project stakeholders to handle the case & reach on decision while the Delay Claim is fresh in mind & before it exacerbates in to dispute.

2 Proactive measures shall be taken to mitigate the consequential impacts of Delay Claims & notified in written as early as possible, this will help the client/consultant for timely investigation in to the conditions identified, and also allows them to consider construction alternatives to limit, or altogether to eliminate the delay, when unavoidable Delay occurs it shall be well recorded with the pertinent detail such as the date & time, location, description, inaddition equipments, materials, and manpower affected in relation to the delay so that it could substantiate the claim with concrete supporting documentation. The view of the contractual parties towards Delay Claims should be balanced, objective, thorough, clear, and sensible.

3 Employers have to make provisions in their contracts that will ensure that contractors submit a baseline programme with CPM network reflecting the true intentions of the contractor with proper logic, realistic duration, and sufficient activity details covering the full scope of the project. The contractor must prepare this using industry standard planning software and submit it electronically to the employer or its representative, once the baseline programme is approved it shall be updated periodically to show the current

status of the project at the time of the delay event, so that will help the before and after impact analysis of the Delay event in the currency of the project.

4 Provision should also be made in the contract for the keeping of records that will provide adequate evidence on the causes of delay and their impacts. Such records should include:

(i) Site progress report: should provide information on the status of all activities in the programme, delays encountered, weather conditions, changes experienced in working conditions due to delay and site resources information (labour, plant and materials). The report must be prepared and issued at regular frequencies as agreed during the joint review meeting.

(ii) RFI reports with its attributes the section of the work requested, the dates, the approval status and the quantity.

(iii) Photos & videos at critical stages of the construction as needed for pictorial representation of the Delay Claim.

5 On selection of the appropriate technique the skill of the analyst as the most important factor shows his knowledge & experience with the existing techniques & their proper application based on other core factors such as availability of records & baseline program. If there is an approved baseline program he should recommend the Net Impact, Time Impact, Snapshot, and Isolated Delay Type Techniques, if in addition to the baseline program a schedule update exists the Time Impact, Snapshot, and Isolated Delay Type are recommended; if neither an approved baseline program nor un update but As-Built records exists he should recommend the Net Impact, Adjusted As-Built CPM, and But For(Collapse) Techniques are highly recommended. It

should be noted that the recommendation given by the analyst should be backed by good factual evidence, effective presentation of that evidence through clear methodical and transparent analysis.

6 Shortage of/slow mobilization of equipment is a procurement problem that can affect the project completion, the lack of equipment may cause major adjustment to project scheduling, methodology revision (i.e. incase of unavailability/replacement) and as a result engender delay, it is recommended that a well-planned equipment/plant procurement schedule & onsite mobilization plan shall be prepared & followed up closely.

Following the above recommendations, parties can employ more reliable DATs such as the Time Impact Analysis, which are capable of producing more accurate results. This will facilitate understanding and agreement among claims parties on the resolution thereby minimising the potential for disputes.

5.3 Recommendation for Further Study

The relative importance weights used in the study were obtained from a cross-sectional survey of claims practitioners from construction organisations. Such coefficients are, however, likely to change with time due to the dynamic nature of the industry which will affect the problem setting of the technique selection. For this reason, it is recommended that similar surveys be repeated at periodic intervals in order to update the study to maintain its accuracy and applicability over time.
Other relevant planning and programming matters that were not investigated in-depth in this research include: common forms of contracts, programming specifications/provisions stipulated therein in managing programmes, records and float ownership. Investigations into these would shed more light on how best delay analysis can be improved to reduce disputes.

The scope of this research was limited to the analysis of Delay Claims that are prepared by local contractors and assessed by local consultants. There is evidence, however, that foreign contractors & consultants are also involved in such claims but their views were not captured due to a potential complication factor and time and cost constrains. Further research is thus required in investigating this area.

In addition, productivity rate of works including those during rainy season and the correct assumptions to consider that will be used for a correct delay analysis shall be done & set as standard performance productivity rate in order to avoid disputes shall be investigated at a further research.

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APPENDIX A

Sample Questionnaire

Section A: General Information

1. Which of the following best describes the nature of your organisation's activities?
(Please tick √ one box)

☐ Contractor ☐ Consultant ☐ Employer

☐ Other(Please Specify)________________________

2. Please give an indication of the size of your organisation in terms of annual turnover.
(Please tick √ one box)

☐ Less Than 100m Birr ☐ 500m -1b Birr

☐ 100m – 500m Birr ☐ Greater Than 1b Birr ☐ Not Applicable

3. Please indicate which of the following best describes your job in the company.
(Please tick √ one box)

☐ Planning ☐ Site Management ☐ External Claim Consultant

☐ Quantity Surveying ☐Office Engineer ☐ Cost Engineer

☐ Contract Management ☐ Others (Please Specify)_____________________

4. **Please indicate your personal experience of the following listed functions**
(Please tick √ one box one box in each row for each function relevant to you)

	Experience (in Years)					
	0	<5	5-10	11-20	21-30	>31
Estimating	☐	☐	☐	☐	☐	☐
Planning	☐	☐	☐	☐	☐	☐
Site Management	☐	☐	☐	☐	☐	☐
Measurement	☐	☐	☐	☐	☐	☐
Claim Preparation	☐	☐	☐	☐	☐	☐
Contract Management	☐	☐	☐	☐	☐	☐

5. **Please indicate the level of involvement of the following parties in the preparation of delay claims generally (Please tick √)**

	Least Involvement				*Highest Involvement*
	1	2	3	4	5
Head of Quantity Surveying	☐	☐	☐	☐	☐
Site Manager(Project Manager)	☐	☐	☐	☐	☐
Head of Planning Department	☐	☐	☐	☐	☐
External Claim Consultant	☐	☐	☐	☐	☐
Others (Please Specify)					
____________________	☐	☐	☐	☐	☐

6. Please indicate the extent of your agreement or disagreement with the following statements about delay claims in practice (Please tick √)

	Strongly Disagree 1	2	3	4	*Strongly Agree* 5
a) The analysis and resolution of most delay claims are left unresolved until nearer the end of the project or after completion before resolving it	☐	☐	☐	☐	☐
b) The resolution of delay claims are often attended by considerable difficulties thereby causing disputes	☐	☐	☐	☐	☐

7. Please indicate the frequency with which each of the following has been the reason for unsatisfactory resolution of your delay claims (Please tick √)

	Not Frequent 1	2	3	4	*Most Frequent* 5
Contractual provisions not properly identified to support claim	☐	☐	☐	☐	☐
Conflicting interpretation of contractual provisions	☐	☐	☐	☐	☐
Failure to establish causal link	☐	☐	☐	☐	☐
Inadequate supporting documentation on Quantum	☐	☐	☐	☐	☐
Inadequate effort at mitigation	☐	☐	☐	☐	☐
Lack of timely notice	☐	☐	☐	☐	☐
Inadequate/incorrect notice	☐	☐	☐	☐	☐
Others (Please Specify)	☐	☐	☐	☐	☐

____

Section B: Schedule Impact Analysis Methodologies and their Usage

8. Please indicate your level of awareness of each of the following methodologies for analysing delays (Indicate by ticking √ the appropriate box)

	Virtually Unaware 1	2	3	4	*Highly Aware* 5
S-curve	☐	☐	☐	☐	☐
Global Impact	☐	☐	☐	☐	☐
Net Impact	☐	☐	☐	☐	☐
Adjusted As-Built CPM	☐	☐	☐	☐	☐
But For(Collapse)	☐	☐	☐	☐	☐
Snapshot	☐	☐	☐	☐	☐
Time Impact	☐	☐	☐	☐	☐
Isolated Delay Type	☐	☐	☐	☐	☐

9. Please indicate the extent to which you use each of the following methodologies for analysing delay claims (Indicate by ticking √ the appropriate box)

	Very Low 1	2	3	4	*Very High* 5
S-curve	☐	☐	☐	☐	☐
Global Impact	☐	☐	☐	☐	☐
Net Impact	☐	☐	☐	☐	☐
Adjusted As-Built CPM	☐	☐	☐	☐	☐
But For(Collapse)	☐	☐	☐	☐	☐
Snapshot	☐	☐	☐	☐	☐

Time Impact	☐	☐	☐	☐	☐
Isolated Delay Type	☐	☐	☐	☐	☐

10. Please indicate the level of success with claims analysed by each of the following methodologies (Indicate by ticking √ the appropriate box)

	Very Low				*Very High*
	1	2	3	4	5
S-curve	☐	☐	☐	☐	☐
Global Impact	☐	☐	☐	☐	☐
Net Impact	☐	☐	☐	☐	☐
Adjusted As-Built CPM	☐	☐	☐	☐	☐
But For(Collapse)	☐	☐	☐	☐	☐
Snapshot	☐	☐	☐	☐	☐
Time Impact	☐	☐	☐	☐	☐
Isolated Delay Type	☐	☐	☐	☐	☐

11. The applicability of schedule delay analysis methodologies to any claim situation depends upon a number of factors. Please rank the following factors, including any additional factors, based on their degree of importance in choosing an appropriate methodology (Please tick √)

	Least Important 1	2	3	4	*Most Important* 5
Availability of records	☐	☐	☐	☐	☐
Availability of baseline programme	☐	☐	☐	☐	☐
Availability of updated programmes	☐	☐	☐	☐	☐
The stage of the project	☐	☐	☐	☐	☐
Reason for the delay analysis	☐	☐	☐	☐	☐
The type of contract	☐	☐	☐	☐	☐
The cost of using the technique	☐	☐	☐	☐	☐
The size of the project	☐	☐	☐	☐	☐
The duration of the project	☐	☐	☐	☐	☐
The complexity of the project	☐	☐	☐	☐	☐
The nature of the delaying events	☐	☐	☐	☐	☐
The skills of the analyst	☐	☐	☐	☐	☐
Number of delays requiring analysis	☐	☐	☐	☐	☐
Others(Please Specify)	☐	☐	☐	☐	☐

____

12. Most practitioners/commentators have sought to explain the relatively low of the methodologies by pointing out perceived obstacles to their successful usage. Please indicate how frequently each of the following factors has been an obstacle to the use of the methodologies in practice.
(Please tick √)

	Not Frequent				*Most Frequent*
	1	2	3	4	5
Lack of familiarity with the technique	☐	☐	☐	☐	☐
High cost involved in its use	☐	☐	☐	☐	☐
Difficulty in using the technique	☐	☐	☐	☐	☐
High time consumption in using technique	☐	☐	☐	☐	☐
Baseline programme without CPM network	☐	☐	☐	☐	☐
Lack of skills in using technique	☐	☐	☐	☐	☐
Lack of suitable programming software	☐	☐	☐	☐	☐
Unrealistic baseline programme	☐	☐	☐	☐	☐
Poorly updated programmes	☐	☐	☐	☐	☐
Lack of adequate project information	☐	☐	☐	☐	☐
Others(Please Specify)	☐	☐	☐	☐	☐

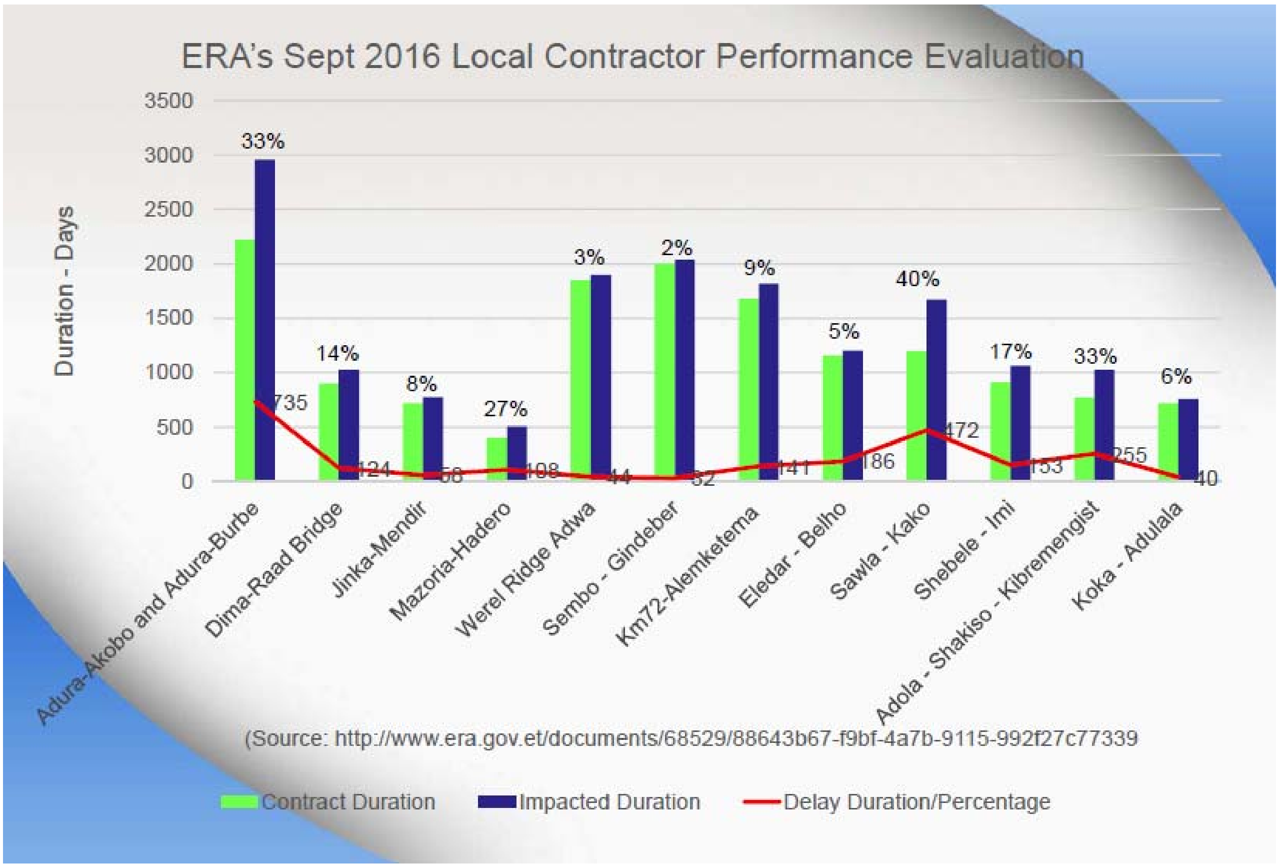
Section C: Delay Causing Factors in the construction Industry

13. What could possibly contribute to delay in your projects.
(Please Tick √ in the table below according to their level of importance)

Groups of factors	No	Factors causing schedule delays	Importance: 1:Very low important	2:Low important	3:Medium important	4: High important	5: Very high important
1)Consultant Related Factors	1	Lack of experience of consultant in construction projects					
	2	Conflicts between consultant and design engineer					
	3	Delay in approving major changes in the scope of work by consultant					
	4	Delay in performing inspection and testing					
	5	Inaccurate site investigation					
	6	Inadequate project management assistance					
	7	Late in reviewing and approving design documents					
	8	Poor communication and coordination with other parties					
2)Contractor Related Factors	1	Frequent change of subcontractors					
	2	Inadequate contractor experience					
	3	Inappropriate construction methods					
	4	Incompetent project team					
	5	Ineffective project planning and scheduling					
	6	Obsolete technology					
	7	Poor communication and coordination with other parties					
	8	Poor site management and supervision					
	9	Rework due to errors					
	10	Unreliable subcontractors					
3)Design Related Factors	1	Complexity of project design					
	2	Design changes by owner or his agent during construction					
	3	Design errors made by designers					
	4	Insufficient data collection and survey before design					
	5	Lack of experience of design team in construction projects					
	6	Mistakes and delays in producing design documents					
	7	Misunderstanding of owner's requirements by design engineer					
	8	Poor use of advanced engineering design software					
	9	Unclear and inadequate details in drawings					
4)Equipment Related Factors	1	Equipment allocation problem					
	2	Frequent equipment breakdowns					
	3	Improper equipment					
	4	Inadequate modern equipment					
	5	Low efficiency of equipment					
	6	Shortage of equipment					
	7	Slow mobilization of equipment					
5)External Related Factors	1	Accidents during construction					
	2	Changes in government regulations and laws					
	3	Conflict, war, and public enemy					
	4	Delay in obtaining permits from municipality					
	5	Delay in performing final inspection and certification by a third party					
	6	Delay in providing services from utilities (such as water, electricity)					
	7	Global financial crisis					
	8	Loss of time by traffic control and restriction at job site					
	9	Natural disasters (flood, hurricane, earthquake)					
	10	Price fluctuations					
	11	Problem with neighbors					
	12	Slow site clearance					
	13	Unexpected surface& subsurface conditions (such as soil, hw table)					
	14	Unfavorable weather conditions					

APPENDIX B

ERA Summary of Local Contractors' Performance Evaluation Reporting Period End of September 2016



APPENDIX C

Factors and groups of schedule delay factors, respondent's scorings

Groups of factors	No	Factors causing schedule delays	Importance					RII	Rank
			1:Very low important	2:Low important	3: Neutral	4: High important	5: Very high important		
1)Consultant Related Factors	1	Lack of experience of consultant in construction projects	2	4	1	2	1	52	36
	2	Conflicts between consultant and design engineer	3		4	3		54	35
	3	Delay in approving major changes in the scope of work by consultant		3	2	4	1	66	19
	4	Delay in performing inspection and testing		4	4	1	1	58	29
	5	Inaccurate site investigation		3	2	4	1	66	17
	6	Inadequate project management assistance		1	4	4	1	70	15
	7	Late in reviewing and approving design documents		2	4	3	1	66	18
	8	Poor communication and coordination with other parties		2	5	2	1	64	23
2)Contractor Related Factors	1	Frequent change of subcontractors	4	4	1	1		38	47
	2	Inadequate contractor experience	2	2		4	2	64	22
	3	Inappropriate construction methods	3		3	2	2	60	27
	4	Incompetent project team	2			5	3	74	11
	5	Ineffective project planning and scheduling	1			3	6	86	2
	6	Obsolete technology	2	1	4	3		56	32
	7	Poor communication and coordination with other parties		1	4	3	2	72	13
	8	Poor site management and supervision		1		7	2	80	4
	9	Rework due to errors	1	2	1	5	1	66	16
	10	Unreliable subcontractors	3	1	2	3	1	56	33
3)Design Related Factors	1	Complexity of project design	1	2	4	3		58	30
	2	Design changes by owner or his agent during construction		2	2	3	3	74	10
	3	Design errors made by designers		3	3	2	2	66	21
	4	Insufficient data collection and survey before design	1		4	3	2	70	14
	5	Lack of experience of design team in construction projects	1	2	5	2		56	31
	6	Mistakes and delays in producing design documents	2	1	4	1	2	60	26
	7	Misunderstanding of owner's requirements by design engineer	2	2	3	3		54	34
	8	Poor use of advanced engineering design software	1	5	2	2		50	38
	9	Unclear and inadequate details in drawings		3	3	2	2	66	20
4)Equipment Related Factors	1	Equipment allocation problem	1		1	5	3	78	9
	2	Frequent equipment breakdowns		1	2	3	4	80	6
	3	Improper equipment	1	1	5	2	1	62	25
	4	Inadequate modern equipment	1	2	4	2	1	60	28
	5	Low efficiency of equipment		1	2	3	4	80	7
	6	Shortage of equipment			1	3	6	90	1
	7	Slow mobilization of equipment			2	3	5	86	3
5)External Related Factors	1	Accidents during construction	3	3	4			42	44
	2	Changes in government regulations and laws	3	5		1	1	44	41
	3	Conflict, war, and public enemy	4	2	2	2		44	42
	4	Delay in obtaining permits from municipality	3	3	2		2	50	39
	5	Delay in performing final inspection and certification by a third party	3	4	2	1		42	45
	6	Delay in providing services from utilities (such as water, electricity)		1	3	2	4	78	8
	7	Global financial crisis	1	6	2	1		46	40
	8	Loss of time by traffic control and restriction at job site	3	4	3			40	46
	9	Natural disasters (flood, hurricane, earthquake)	5	2	1	1	1	42	43
	10	Price fluctuations	2	3	2	3		52	37
	11	Problem with neighbors	5	5				30	48
	12	Slow site clearance	2	3		2	3	62	24
	13	Unexpected surface& subsurface conditions (such as soil, hw table)			4	2	4	80	5
	14	Unfavorable weather conditions	1	1	2	2	4	74	12

APPENDIX D

Group factors according to Equivalent Relative Index Scoring

Groups of factors	No	Factors causing schedule delays	RII	P_n	Pn X RII	$ERII = \frac{\sum Pn \times RII}{\sum Pn}$
Equipment Related Factors	1	Equipment allocation problem	78	5	390	71.26
	2	Frequent equipment breakdowns	80	3	240	
	3	Improper equipment	62	6	372	
	4	Inadequate modern equipment	60	7	420	
	5	Low efficiency of equipment	80	3	240	
	6	Shortage of equipment	90	1	90	
	7	Slow mobilization of equipment	86	2	172	
Contractor Related Factors	1	Frequent change of subcontractors	38	10	380	58.58
	2	Inadequate contractor experience	64	6	384	
	3	Inappropriate construction methods	60	7	420	
	4	Incompetent project team	74	3	222	
	5	Ineffective project planning and scheduling	86	1	86	
	6	Obsolete technology	56	8	448	
	7	Poor communication and coordination with other parties	72	4	288	
	8	Poor site management and supervision	80	2	160	
	9	Rework due to errors	66	5	330	
	10	Unreliable subcontractors	56	9	504	
Consultant Related Factors	1	Lack of experience of consultant in construction projects	52	8	416	58.42
	2	Conflicts between consultant and design engineer	54	7	378	
	3	Delay in approving major changes in the scope of work by consultant	66	2	132	
	4	Delay in performing inspection and testing	58	6	348	
	5	Inaccurate site investigation	66	2	132	
	6	Inadequate project management assistance	70	1	70	
	7	Late in reviewing and approving design documents	66	2	132	
	8	Poor communication and coordination with other parties	64	5	320	
Design Related Factors	1	Complexity of project design	58	6	348	57.55
	2	Design changes by owner or his agent during construction	74	1	74	
	3	Design errors made by designers	66	3	198	
	4	Insufficient data collection and survey before design	70	2	140	
	5	Lack of experience of design team in construction projects	56	7	392	
	6	Mistakes and delays in producing design documents	60	5	300	
	7	Misunderstanding of owner's requirements by design engineer	54	8	432	
	8	Poor use of advanced engineering design software	50	9	450	
	9	Unclear and inadequate details in drawings	66	3	198	
External Related Factors	1	Accidents during construction	42	11	462	44.43
	2	Changes in government regulations and laws	44	8	352	
	3	Conflict, war, and public enemy	44	8	352	
	4	Delay in obtaining permits from municipality	50	6	300	
	5	Delay in performing final inspection and certification by a third party	42	11	462	
	6	Delay in providing services from utilities (such as water, electricity)	78	2	156	
	7	Global financial crisis	46	7	322	
	8	Loss of time by traffic control and restriction at job site	40	13	520	
	9	Natural disasters (flood, hurricane, earthquake)	42	10	420	
	10	Price fluctuations	52	5	260	
	11	Problem with neighbors	30	14	420	
	12	Slow site clearance	62	4	248	
	13	Unexpected surface& subsurface conditions (such as soil, hw table)	80	1	80	
	14	Unfavorable weather conditions	74	3	222	

APPENDIX E

Spearman Rank Order Correlation Coefficient Result

Awarness Vs Usage Correlations

			Overall Awarness	Overall Usage
Spearman's rho	Overall Awarness	Correlation Coefficient	1.000	.929**
		Sig. (2-tailed)		.050
		N	8	8
	Overall Usage	Correlation Coefficient	.929**	1.000
		Sig. (2-tailed)	.050	
		N	8	8

**. Correlation is significant at the 0.05 level (2-tailed).

Usage Vs Success Correlations

			Overall Usage	Overall Success
Spearman's rho	Overall Usage	Correlation Coefficient	1.000	.857**
		Sig. (2-tailed)		.050
		N	8	8
	Overall Success	Correlation Coefficient	.857**	1.000
		Sig. (2-tailed)	.050	
		N	8	8

**. Correlation is significant at the 0.05 level (2-tailed).

APPENDIX F

Reliability Analysis

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.939	.937	48

Item-Total Statistics

Item	Item Description	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
VAR1	Equipment allocation problem	141.2000	675.067	.769	.935
VAR2	Frequent equipment breakdowns	141.3000	678.011	.833	.935
VAR3	Improper equipment	140.5000	694.500	.612	.937
VAR4	Inadequate modern equipment	141.1000	692.767	.671	.937
VAR5	Low efficiency of equipment	140.7000	707.567	.395	.938
VAR6	Shortage of equipment	140.6000	714.711	.290	.939
VAR7	Slow mobilization of equipment	140.7000	690.233	.813	.936
VAR8	Frequent change of subcontractors	141.1000	705.656	.574	.937
VAR9	Inadequate contractor experience	141.9000	682.100	.856	.935
VAR10	Inappropriate construction methods	140.7000	654.233	.930	.934
VAR11	Incompetent project team	141.0000	658.444	.889	.934
VAR12	Ineffective project planning and scheduling	140.3000	671.122	.772	.935
VAR13	Obsolete technology	139.7000	688.011	.633	.937
VAR14	Poor communication and coordination with other parties	141.2000	713.511	.250	.939
VAR15	Poor site management and supervision	140.5000	709.389	.450	.938
VAR16	Rework due to errors	140.0000	712.000	.376	.938
VAR17	Unreliable subcontractors	140.8000	687.289	.663	.936
VAR18	Lack of experience of consultant in construction projects	141.4000	678.044	.715	.936
VAR19	Conflicts between consultant and design engineer	141.1000	700.544	.525	.937
VAR20	Delay in approving major changes in the scope of work by consultant	140.5000	699.611	.472	.938
VAR21	Delay in performing inspection and testing	140.8000	684.844	.703	.936
VAR22	Inaccurate site investigation	140.5000	704.278	.396	.938
VAR23	Inadequate project management assistance	141.2000	697.733	.734	.937
VAR24	Late in reviewing and approving design documents	141.1000	678.322	.788	.935

Item	Item Description	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
VAR25	Poor communication and coordination with other parties	141.3000	686.011	.766	.936
VAR26	Complexity of project design	141.2000	690.622	.693	.936
VAR27	Design changes by owner or his agent during construction	140.7000	696.678	.540	.937
VAR28	Design errors made by designers	140.1000	683.433	.706	.936
VAR29	Insufficient data collection and survey before design	140.0000	708.667	.390	.938
VAR30	Lack of experience of design team in construction projects	141.2000	699.067	.605	.937
VAR31	Mistakes and delays in producing design documents	140.9000	764.100	-.550	.945
VAR32	Misunderstanding of owner's requirements by design engineer	140.0000	710.000	.365	.938
VAR33	Poor use of advanced engineering design software	139.4000	711.600	.483	.938
VAR34	Unclear and inadequate details in drawings	139.7000	710.233	.463	.938
VAR35	Accidents during construction	141.8000	753.733	-.503	.943
VAR36	Changes in government regulations and laws	142.0000	716.889	.270	.939
VAR37	Conflict, war, and public enemy	141.8000	705.956	.396	.938
VAR38	Delay in obtaining permits from municipality	141.3000	694.678	.421	.939
VAR39	Delay in performing final inspection and certification by a third party	141.7000	719.122	.183	.940
VAR40	Delay in providing services from utilities (such as water, electricity)	140.1000	712.322	.307	.939
VAR41	Global financial crisis	141.7000	728.456	.043	.940
VAR42	Loss of time by traffic control and restriction at job site	141.7000	709.344	.362	.939
VAR43	Natural disasters (flood, hurricane, earthquake)	142.1000	695.433	.621	.937
VAR44	Price fluctuations	141.4000	716.933	.211	.940
VAR45	Problem with neighbors	142.3000	716.678	.351	.939
VAR46	Slow site clearance	140.6000	723.378	.048	.942
VAR47	Unexpected surface& subsurface conditions (such as soil, hw table)	140.1000	718.989	.213	.939
VAR48	Unfavorable weather conditions	140.3000	703.344	.351	.939

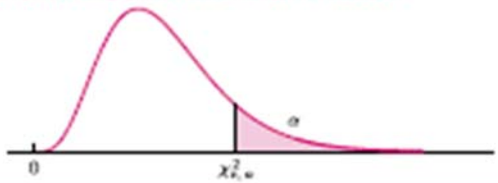
Scale Statistics

Mean	Variance	Std. Deviation	N of Items
143.9000	730.322	27.02447	48

APPENDIX G

Chi-Square Critical Table

TABLE A.7 Upper percentage points for the χ^2 distribution

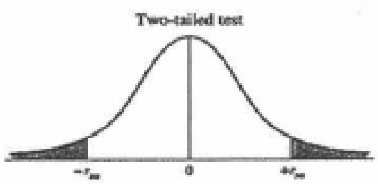


ν	α: 0.995	0.99	0.975	0.95	0.90	0.10	0.05	0.025	0.01	0.005
1	0.000	0.000	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.070	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.300
13	3.565	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000	34.267
17	5.697	6.408	7.564	8.672	10.085	24.769	27.587	30.191	33.409	35.718
18	6.265	7.015	8.231	9.390	10.865	25.989	28.869	31.526	34.805	37.156
19	6.844	7.633	8.907	10.117	11.651	27.204	30.144	32.852	36.191	38.582
20	7.434	8.260	9.591	10.851	12.443	28.412	31.410	34.170	37.566	39.997
21	8.034	8.897	10.283	11.591	13.240	29.615	32.671	35.479	38.932	41.401
22	8.643	9.542	10.982	12.338	14.041	30.813	33.924	36.781	40.289	42.796
23	9.260	10.196	11.689	13.091	14.848	32.007	35.172	38.076	41.638	44.181
24	9.886	10.856	12.401	13.848	15.659	33.196	36.415	39.364	42.980	45.559
25	10.520	11.524	13.120	14.611	16.473	34.382	37.652	40.646	44.314	46.928
26	11.160	12.198	13.844	15.379	17.292	35.563	38.885	41.923	45.642	48.290
27	11.808	12.879	14.573	16.151	18.114	36.741	40.113	43.195	46.963	49.645
28	12.461	13.565	15.308	16.928	18.939	37.916	41.337	44.461	48.278	50.993
29	13.121	14.256	16.047	17.708	19.768	39.087	42.557	45.722	49.588	52.336
30	13.787	14.953	16.791	18.493	20.599	40.256	43.773	46.979	50.892	53.672
31	14.458	15.655	17.539	19.281	21.434	41.422	44.985	48.232	52.191	55.003
32	15.134	16.362	18.291	20.072	22.271	42.585	46.194	49.480	53.486	56.328
33	15.815	17.074	19.047	20.867	23.110	43.745	47.400	50.725	54.776	57.648
34	16.501	17.789	19.806	21.664	23.952	44.903	48.602	51.966	56.061	58.964
35	17.192	18.509	20.569	22.465	24.797	46.059	49.802	53.203	57.342	60.275
36	17.887	19.233	21.336	23.269	25.643	47.212	50.998	54.437	58.619	61.581
37	18.586	19.960	22.106	24.075	26.492	48.363	52.192	55.668	59.893	62.883
38	19.289	20.691	22.878	24.884	27.343	49.513	53.384	56.896	61.162	64.181
39	19.996	21.426	23.654	25.695	28.196	50.660	54.572	58.120	62.428	65.476
40	20.707	22.164	24.433	26.509	29.051	51.805	55.758	59.342	63.691	66.766

For $\nu > 40$, $\chi^2_{\nu,\alpha} \approx 0.5(z_\alpha + \sqrt{2\nu - 1})$.

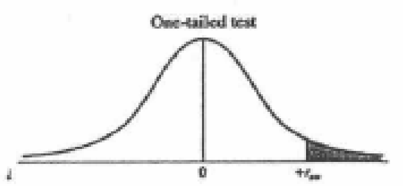
APPENDIX H

Critical Values of the Spearman Rank Order Correlation Coefficients: The r_s Tables



Level of Significance

N	α = .05	α = .01
5	1.000	–
6	.886	1.000
7	.786	.929
8	.738	.881
9	.700	.833
10	.648	.794
11	.618	.755
12	.587	.727
13	.560	.703
14	.538	.675
15	.521	.654
16	.503	.635
17	.485	.615
18	.472	.600
19	.460	.584
20	.447	.570
21	.435	.556
22	.425	.544
23	.415	.532
24	.406	.521
25	.398	.511
26	.390	.501
27	.382	.491
28	.375	.483
29	.368	.475
30	.362	.467
31	.356	.459
32	.350	.452
33	.345	.446
34	.340	.439
35	.335	.433
36	.330	.427
37	.325	.421
38	.321	.415
39	.317	.410
40	.313	.405
41	.309	.400
42	.305	.395
43	.301	.391
44	.298	.386
45	.294	.382
46	.291	.378
47	.288	.374
48	.285	.370
49	.282	.366
50	.279	.363



Level of Significance

N	α = .05	α = .01
5	.900	1.000
6	.829	.943
7	.714	.893
8	.643	.833
9	.600	.783
10	.564	.745
11	.536	.709
12	.503	.671
13	.484	.648
14	.464	.622
15	.443	.604
16	.429	.582
17	.414	.566
18	.401	.550
19	.391	.535
20	.380	.520
21	.370	.508
22	.361	.496
23	.353	.486
24	.344	.476
25	.337	.466
26	.331	.457
27	.324	.448
28	.317	.440
29	.312	.433
30	.306	.425
31	.301	.418
32	.296	.412
33	.291	.405
34	.287	.399
35	.283	.394
36	.279	.388
37	.275	.383
38	.271	.378
39	.267	.373
40	.264	.368
41	.261	.364
42	.257	.359
43	.254	.355
44	.251	.351
45	.248	.347
46	.246	.343
47	.243	.340
48	.240	.336
49	.238	.333
50	.235	.329

Adapted from Zar, J. H. (1972). Significance testing of the Spearman rank correlation. *Journal of the American Statistical Association.* 67, 578 – 580.

APPENDIX I

Briefing On Delay Analysis Techniques

1. S Curve(Dollar to Time Relation Ship)

This methodology analyses delay based on the relationship between cost and time. It involves developing a time/cost S-curve for the original plan together with the Scurve representing actual income. The actual S-curve must exclude any cost for additional works so that comparison of the two curves is valid. The amount of delay at any point along the actual curve is the horizontal distance between these curves at this point. The limitations of this technique are as follows: it does not identify and track the activities on the critical path; the original planned S-curve might not be accurate due to "front end loading" or other factors; payments for stored materials and equipment could result in misleading progress of an updated S-curve.

2. Global Impact Technique

The global impact technique is a simplistic approach to depict the effect of time overrun causing events. It is often used by claimants in their initial requests for time extension, usually during the construction phase. In this method, all time overruns and similar occurrences are simply plotted on summary bar charts. The delay start & finish dates are determined for each event, and the duration of each delaying event is computed. The total extension of time of the project is calculated to be the sum total of the durations of all delaying events.

3. Net Impact Technique (As Panned Vs As Built /Bar Chart Analysis/As-Built Bar Chart)

This method depicts only the net effect of all claimed delays on a bar chart. In implementing this technique, all delays, disruptions, and suspensions, even change orders are plotted on as-built schedule. The main argument focuses on the combined overwhelming effect of all delays on the completion date of the project. Thus only the net effect of delays is calculated and the requested time extension is then the difference between the as-planned and the as-built completion date. The net impact technique unlike the global impact attempts to deal with the issue of concurrent delays.

4. The Adjusted As-Built CPM Technique (Total Time/Impacted As-Built CPM)

This technique utilizes the CPM format to develop an as-built schedule for the entire project. Delaying events are depicted as distinct activities and linked to the specific work activity in the network by restraints. The critical path of the project is determined twice, the adjusted as-built completion date and the as-planned completion date is the amount of time the claimant would ask for compensation. The as-built CPM method may weed out minor delays that would not affect critical activities. This technique is similar to the net impact technique in that both techniques only show the net effect of all claimed delays on the project completion date.

5. But for(Collapse) Technique (As-Built Subtracting Impacts/As-Built Minus Analysis)

The basic concept of the But For technique is that the opposite party can be shown to be liable through a CPM analysis, that deals with the two parties' impacts separately. Delaying events for which the claimant is willing to accept responsibility is incorporated in to the as-planned CPM schedule, and the recalculation of the project completion date is performed. The as-built schedule is compared to the adjusted schedule(Calculated), and the conclusion drawn is that the difference between the as-built and the revised completion dates is the time effect of delays which were beyond the claimant's control. The duration of the claimed delays will be subtracted out from

the total variance, leaving the balance to the other party. But for the other party's delays, the project would have been completed in a timely manner.
If the contractor is using this method the analysis would include only nonexcusable (Contractor's fault) delays in to the as-planned schedule. The result of the adjusted schedule would generate a revised completion date, which is due to contractor's delays. The difference between the as-built and the revised completion date is due to the owner. The logic is that despite all of the contractor's delays the project is still impacted which is the responsible of the owner, and the rest of the total delays is due to the contractor. Conversely, the owner can use the same technique, but would include in to the as-planned schedule, only excusable delays for which the owner accepts responsibility.

6. Snapshot Technique (Window Analysis/Watershed/Periodic Update Analysis)

The snapshot technique is used to determine the amount of delay that has occurred on a project, the time when the delay occurred, and what was the cause of the delay. The snapshot technique utilizes the as-planned, the as-built and any revised schedule that have been implemented during the execution of the project. The total project duration is divided into a number of time periods, or snapshots. These snapshots dates are usually selected to coincide with major project milestones, significant changes in planning, or when major delays or group of delays are known to have occurred. For the first snapshot the analysis starts by inserting the delaying events into the as-planned schedule, and a new schedule duration is generated. In the next snapshot the durations and the relationships of the activities are taken from the as-built schedule, for the snapshot period, and are incorporated into the schedule generated from the previous snapshot, thus an extended duration schedule is established. The new completion date is compared to that of the project prior to performing the snapshot under consideration. The difference between the two completion dates is the amount of delay that affected the project as a result of the delaying events which have occurred during the snapshot period. Once the time impact has been determined, the causes of delays are assessed.

Before starting the next snapshot analysis, the schedule has to be revised, if necessary, to reflect the planning of the project at that point in time under consideration. When the revisions are done, the difference in the project completion date of the extended duration and the revised extended duration schedules is an indication of acceleration (or relaxation) achieved through change in planning. The revised extended duration schedule now becomes the baseline schedule for the next snapshot analysis.

7. Time Impact Technique (End of Every Delay Analysis/Chronological and Cumulative Approach)

The time impact technique, is similar to the snapshot technique in examining the effects of delays at different times in the project. But the difference is that the time impact technique focuses on specific delay not at a time period containing delays. The idea is to obtain a “stop action” picture of the project before and/or after encountering a major impact on the schedule.
The as-planned is first verified to reflect the contractor’s actual plan, and second, it must be updated at certain critical periods in the construction process, thereafter the actual duration of the project is established. The delay is inserted into the schedule, the project duration is recalculated, and a new project completion date is determined. The difference between the two completion dates is the effect that the delay had on the project at the time it was inserted into the schedule.

This Technique is progressively applied for each delay or delaying event which is to be analyzed. In order to obtain an accurate impact upon the overall project completion date, the schedule should be updated with actual dates and durations prior to incorporating the analyzed delay.
This ensures that critical paths are accurate at the time of the delay is being analyzed. By adding all the individual time impact analyses, a total impact of delays on the

project completion date is determined. This amount of total delays is then analyzed for apportionment between the owner and the contractor.

8. Isolated Delay Type Technique

In performing the isolated delay type technique, which applies only the relevant portion of the delays in the time period, with in an as-planned schedule. Comparing the project's completion date before and after inserting the delaying events may generate a change in the project's completion date. The discrepancy is attributed to the delay that was incorporated into the schedule. When applying this technique from the contractor's point of view, excusable compensable and excusable non compensable delays are incorporated in the schedule in order to calculate an adjusted schedule. This schedule is compared to against the previous one and the variance is the amount of time the contractor was justifiably delayed. However, to find the amount of time the contractor can seek compensation, only excusable delays are incorporated in the schedule and the difference between the two completion dates is calculated. Conversely, the owner can use this technique to measure the amount of time that he is entitled to liquidated damages from the contractor. The nonexcusable delays would be incorporated to determine a new adjusted schedule, thus the discrepancy between the two schedules would be the amount of time to quantify the liquidated damages.